W. B. No. 913

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### WEATHER OF THE MONTH



### CHARTS



† In marine separate.

### CORRECTIONS

JULY, 1926, page 317:

*Florida Peninsula* section, the *departure from normal temperature* should be −0.2; for Miami the *departure* should be −1.1.

OCTOBER, 1926, page 449:

*Florida Peninsula* section, the *number of cloudy days* (reading downward) should be: 5, 7, 3, 5; the *average cloudiness*, 3.9, 5.5, 4.1, 3.4, respectively.

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## APPLICATION OF THE POLAR-FRONT THEORY TO A SERIES OF AMERICAN WEATHER MAPS[1]


By CARL-GUSTAF ROSSBY and RICHARD HANSON WEIGHTMAN

[U. S. Weather Bureau, Washington, January, 1927]



SYNOPSIS

1. In order to show the applicability of the polar-front theory to the study of American weather a series of synoptic maps, comprising the period February 16–19, 1926, has been subjected to a detailed analysis by the methods of the Norwegian Meteorological School. The type discussed below, a weak depression from the Northwest slowly approaching the lower Mississippi Valley, and there increasing in intensity under advection of warm, moist air from the Gulf and cold air from Canada, occurs frequently. It offers a good example for analysis, as the depression is built up of at least four different air masses. It is found that in spite of the few data from the West the history of the LOW can be satisfactorily outlined, at least in its general features.

2. The methods used in locating the fronts are discussed, several examples being given.

3. The upper-air data are discussed and employed for identification of the different air masses. The free-air temperatures prove very valuable for this purpose, since in the upper levels the air masses seem to a great extent to preserve their characteristic temperatures.

4. The aerological data are also used for a discussion of the stability of the atmosphere over the Gulf States. In this connection upper-air convection in the South is treated and reasons given why this kind of convection plays such an important rôle in the United States while it is almost without significance in Europe.

5. As a result of the analysis of the maps according to the polar-front theory it is found that several improvements in the character and amount of the observations in this country are highly desirable and some suggestions to that effect are offered.


### INTRODUCTION

In this article are given the results of a study of weather maps carried on by the authors in the summer and fall of 1926. In taking up this work, the intention was to show in the first place how and to what extent the Norwegian methods of analyzing synoptic maps could be applied to the study of American weather. Furthermore, it seemed desirable to ascertain what modifications, if any, in these theories would be required and finally to determine whether any change in the present system of observations might be needed in order to facilitate an application of the Norwegian methods to the daily forecast work in the United States. With these objects in mind it was decided to follow in detail the movements of the different air masses and fronts on a selected series of weather maps. It would, of course, have been possible to take a synoptic chart showing a cyclone of clear-cut structure with a well marked warm sector but the application of the polar-front theory to such a special case would not have given a satisfactory answer to the general question of whether or not a satisfactory determination of fronts is possible on our maps in general and also whether it is possible to understand the physical processes in operation. A series was therefore selected which, so far as complexity is concerned, leaves nothing to be desired. The maps chosen afford examples of occlusions, a regeneration and a formation of a secondary according to the wave theory of cyclones. We are well aware that in certain details several of the conclusions reached may be subject to error but, it is believed that in the main our analysis describes the behavior of the fronts correctly.

The first section contains a general description of the synoptic charts with special reference to the fronts and precipitation areas. To follow this part to the best advantage, frequent reference to the lithograph maps 1 to 7 is necessary. In the next section are given a few examples of the methods pursued in locating the fronts The third section is devoted to a study of available free air data for the period under discussion. So far as possible, they have been used to verify the location and movements of the fronts. Section four treats the question of upper air convection which, in the papers published heretofore by the Norwegian school, has been almost entirely left out of consideration but which is essential for the explanation of certain types of cyclonic rain in the United States. Finally in the last section suggestions are offered as to desirable extensions in the network of stations and additional data to be included in the telegraphic reports of observations. The reader is supposed to be familiar with the fundamentals of the modern ideas concerning the structure of cyclones (*see* bibliography).

### I. DESCRIPTION OF THE FRONTS AND PRECIPITATION AREAS

The period under discussion extends from February 16, 8 a. m. to February 19, 8 a. m., 1926. Maps for 8 a. m. and 8 p. m. each day are reproduced and numbered 1 to 7, an explanation of the symbols and notations being given on each map.[2]

For several days prior to the 16th, as shown by the northern hemisphere weather charts, a low pressure area moved slowly eastward over the Aleutian Islands, while south of its center several secondaries moved eastward to the North Pacific Coast. One of these, attended by a warm front, reached the North Pacific Coast on the 14th, at which time a cold front was some distance off the California coast. On the evening of the 15th the rain belt along this warm front covered southern Washington and the greater part of Idaho, while the air behind the cold front, $C_p$, had overspread Northern California as indicated by the double red line marked "February 15, p. m." on map 1. By the morning of the 16th it had overtaken the warm front and an occlusion took place with rain over southern Washington and northwestern Idaho.

As frequently occurs in such cases, the low center was apparently displaced to the south or southeast of the occlusion, the low center $D_1$ on the morning of the 16th being central over Utah. The warm front, $W_1$, may be

[1] This study was begun during a temporary appointment of Mr. Rossby in the Weather Bureau but was completed during his employment under "The Daniel Guggenheim Fund for the Promotion of Aeronautics."

[2] Temperatures given in this paper are in Fahrenheit unless otherwise indicated.

continued southward through Utah and Arizona, and thence southeastward through the Rio Grande Valley. It may be connected with a cold front $C_1$ over the southern Gulf and western Atlantic. This cold front $C_1$, attended the eastward movement of a trough of low pressure off the Atlantic Coast, and has by the morning of the 16th advanced eastward nearly to Bermuda and southward to the Florida Straits. Behind $C_1$ a deep mass of cold air $P_1$ has accumulated over the Atlantic States and Ohio Valley (see Sec. III, also Fig. 4). As a result the pressure system shows an anticyclone, $H_1$, central over the Ohio Valley, the origin of which may be traced to Alberta. During its movement southeastward it has left behind a thin layer of polar air over the Plains States, the West Gulf States and upper Mississippi Valley. Above this thin layer we find (see Sec. III) a relatively mild dry westerly wind which will be designated the M current, but which will serve as polar air relative to the depression $D_1$. Between the warm front $W_1$ and the cold front $C_p$ we have a warm sector made up of a current of comparatively warm air of Pacific origin, $T_p$.

The anticyclone $H_2$ is increasing in intensity over a snow covered region and more and more cold air, $P_2$, is accumulating behind the cold front, $C_2$. When sufficient polar air has accumulated this cold mass will tend to move southward in the form of a more or less well-developed cold wave, which in the developments to follow will be of great importance.

On map 2 (Feb. 16, p. m.) the depression, $D_1$, has moved southeastward, being central over Colorado. From this center the occluded front, which is gradually disappearing, extends northwestward. The fresh polar air, $P_2$, from the Canadian Northwest is spreading southward and the western part of the cold front, $C_2$, now almost coincides with the occlusion. The polar air, $P_2$, is much colder than the Pacific air, $P_p$, behind the occlusion and we may therefore expect that the former will partly push away the Pacific air and spread southward on the western side of $D_1$.

In the South, warm, moist air, $T_m$, from the Gulf has begun to move northward over the thin layer of polar air ($P_1$) covering the West Gulf States, and this ascent over a heavier air mass has given rise to the development of a rain area over southern Texas.

The depression, $D_2$, is now located northwest of Lake Superior and the circulation has increased somewhat in intensity. A regular warm front rain belt has developed northeast and east of Lake Superior, but the mild M air is still separated from the ground by a thin layer of $P_1$ air, so that no real warm air is discernible at the surface. This mild M air over Wisconsin and Iowa seems to be flowing in a valley between the colder $P_2$ air over the Dakotas and the cold $P_1$ air remaining over the Atlantic States and the Ohio Valley.

On map 3 (Feb. 17, a. m.) the depression, $D_1$, has been displaced still farther southward under the influence of

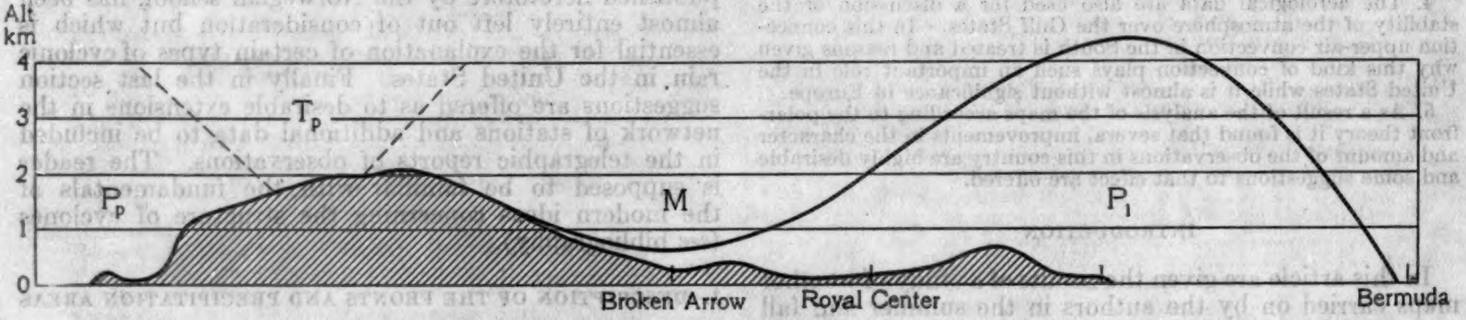



FIG. 1.—Vertical section of the atmosphere along latitude 37°, February 16, 8 a. m.

The LOW $D_2$ over Manitoba has advanced southeastward from British Columbia. This LOW is maintained by the relatively warm M air and the cold $P_2$ current over Saskatchewan, but, since the M air is separated from the ground by the thin layer of $P_1$ air mentioned before, the depression has no well-developed warm sector at the surface.

The origin of the upper current over the Plains States and upper Mississippi Valley is somewhat uncertain, but, judging from its low humidity, it can not be of Gulf origin, but must have come at least in major part across the mountains from the Pacific. Kite ascents at Drexel and Ellendale show that this mild air appears as low down as 500 m.

To illustrate the distribution of the different air masses, a vertical section for the 16th 8 a. m. is given along latitude 37°. (See Fig. 1.) With the aid of the upper air data from Washington, Broken Arrow and Royal Center (afternoon flight) it has been possible to draw fairly well the boundary between the M and the $P_1$ air. It is not possible to determine the boundaries between the $P_p$, $T_p$, and M currents on account of the absence of upper air data from the Western States, but considering the relative densities of the three air masses as inferred from the surface temperatures and the position of the fronts at the surface, we may conclude that they are distributed approximately as indicated by the broken lines in the figure.

the heavy polar air, $P_2$, north of it. The occlusion and the western part of the new cold front $C_2$ have joined and play the rôle of a well-marked secondary cold front to $D_1$, ($C_2$). The cold front, $C_p$, extends from the depression, $D_1$, southward and then westward over northwestern Mexico. The small rain belts over northern Missouri, lower Michigan, and at Doucet, Quebec, may be explained as a kind of warm front rain. As the $P_2$ current spreads slowly southeastward the mild M current in front of it, which is made up of several strata the densities of which increase from northwest to southeast, tries to escape to the east. As a result the warmer layers of the M current will slide up along and over the colder ones, in this manner producing a light, warm front rain (St. Joseph 0.06 inch, Grand Haven 0.07, and Doucet 0.10). That the density of the M current actually increases from northwest to southeast, at least in the lower levels, is seen from the morning kite ascents, the temperature at 1,000m being 3.3° C. at Royal Center and 0.7° C. at Washington, and at 1,500 meters 0.7° C. at Royal Center and −0.3° C. at Washington. At higher levels the density changes in the opposite way.

The polar air, $P_1$, which has been carried around the anticyclone centered over Virginia, has been heated from below through contact with the warm water of the Gulf. This heated polar air will be studied more closely in Section III, and is there denoted as $M_1$ air. On account of this heating it is very difficult to trace the exact posi-

tion of the front $W_1$, which, under the influence of the increasing southerly current, $T_m$, has begun to move northward. It seems, however, as if northeastern Texas was still covered with a thin layer of heated $P_1$ air ($M_1$). The rain belt, which on the preceding map was located over Texas on the northern side of $W_1$, has moved northeastward during the night and is now over Louisiana and Arkansas. Even in its eastern part the warm front ($W_1$) has moved slowly northward under the influence of the southwesterly $T_m$ current and seems to be located between Miami and Ft. Myers.

On map 4 we find the depression, $D_1$, displaced still more to the east and south, being now central over Oklahoma. The cold front, $C_p$, extends from the center southward to northeastern Mexico and thence probably westward. The western part of the cold front, $C_2$, extends from $D_1$ northwestward. In comparing this map with the preceding one, it is seen that the polar air, $P_2$, is spreading southward to the west of the depression.

The $T_m$ air has now worked down to the surface over the greater part of Texas and southern Louisiana. The warm front, $W_1$, passes immediately north of New Orleans and continues eastward between Titusville and Jacksonville. The rising pressure north of the front, $C_2$, shows that the $P_2$ air mass is slowly pressing the entire system southeastward, lifting the M air and thus producing a broad rain belt along the front.

During the next 12 hours the cold front $C_p$ overtakes the western part of the warm front $W_1$. As a consequence the rain belt along the latter has almost entirely disappeared on Map 5 (Feb. 18, 8 a. m.), while the rain belt along the eastern part of $C_2$ remains unchanged in extent. On map 4 the development of a wave-like disturbance off the South Atlantic coast along the eastern part of $W_1$ was indicated. This wave has continued to develop and move northward simultaneously with the formation of a rain belt over Georgia, the Carolinas and extreme northwestern Florida. This wave, as seen on the following maps, will develop into a secondary with closed isobars.

The western part of the cold front, $C_2$, has moved entirely around the center of the depression $D_1$, and the polar air $P_2$ has reached northern Texas. Thus the Pacific air, $P_p$ is restricted to a rather narrow, spiral form of wedge extending from the Texas coast into the center of $D_1$.

On map 6 (Feb. 18 p. m.) we find that $D_1$ has moved eastward. It is now central over southeastern Missouri. The secondary which on the preceding map was central over Georgia has moved northward up the South Atlantic coast and increased in intensity, so that now a separate low pressure center, $D_3$, is found over North Carolina.

The area of rain over Georgia and northern Florida must be explained to a great extent as due to upper air convection, produced as the warm $T_m$ current penetrates under the somewhat colder $T_p$ current. (See Sec. IV, p. 492.) The convectional character of the rain is obvious from the fact that thunderstorms occurred at Atlanta and Thomasville.

The cold air, $P_2$, continuing to move southward behind $D_1$ now covers Texas, and is beginning to spread over the Gulf of Mexico. The cold front $C_p$ has also moved eastward and now extends from Alabama southward. The occluded part of the front continues to decrease in intensity. At the point south of the occlusion where $C_p$ and $W_1$ branch out there would ordinarily develop a new secondary center $D_4$. However, the three centers $D_1$, $D_3$, and $D_4$ are so close to each other that the individual circulations around them markedly influence each other and have a tendency to join in a single circulation in the same way that vortex experiments have shown small water whirls rotating in the same direction to have a tendency to join and form a single large whirl.

Map 7 (Feb. 19, 8 a. m.) shows a continued displacement of the center $D_1$, toward the east. The cold front $C_2$ has now taken the form of a line extending from New England southwestward to extreme northwestern Florida, behind which the cold air $P_2$ flows unhindered over the Gulf of Mexico. The $D_3$ center has moved northward to northern Virginia, while what remains of the $D_4$ center is over northeastern South Carolina. The front $W_1$–$C_p$ is still accompanied by an extensive rain belt along the middle and south Atlantic coast, which is clearly separated from the rain belt behind $C_2$ by a region without precipitation over the southern Appalachians. The whole low pressure system over the Atlantic States has deepened (in other words, the circulation has increased in intensity) during the last 12 hours. The lowest pressure is 29.56 on the 18 p. m. while on the 19 a. m. it is 29.36.

This increase in intensity of the circulation may be explained as a result of the gradual disappearance of the two sectors M and $P_p$, separating the warm $T_m$ and the cold $P_2$ currents. Thus the temperature differences at the $W_1$–$C_p$ and the $C_2$ fronts are added. In the subsequent developments we may expect the transition layers between $T_m$ and $P_2$ to disappear entirely and a single well marked discontinuity to develop.

## II. EXAMPLES OF METHODS USED IN LOCATING FRONTS

A few examples will be given illustrating how the position of a front is determined by means of the ordinary surface observations.

For this purpose we may start with the warm front $W_1$ on map 4: We see on this map a rain area extending from the center $D_1$ over Oklahoma, east southeastward to Alabama. This rain area is of the broad type which generally accompanies a warm front. We should therefore most naturally expect to find some discontinuity in the meteorological elements in that region. In the rain belt the winds are mostly east or southeast, while south of it they are all southerly. Thus, it is logical to place a warm front tentatively along the southern limit of the rain belt. That would mean that we have to explain the rain belt as the result of the up-grade movement of the southerly current over the east and southeasterly winds in the rain belt. If we look a little closer at the data, we find that the temperatures are in good agreement with this hypothesis. Within the southerly current the temperatures vary from 70° at Brownsville and New Orleans to 62° at Fort Worth. In the relatively cold $P_1$ current, temperatures range from 60° at Shreveport and Mobile to 48° at Little Rock. Thus we see that, while the tentative front is not accompanied by a marked temperature discontinuity, it distinctly separates two air masses which, considered as a whole, are of very different temperatures. Furthermore, the cloud observations confirm the hypothesis that warm air is sliding upward over the colder southeasterly current. Thus Vicksburg with a surface wind from the southeast reports nimbus moving from the southwest and Fort Smith with easterly surface wind reports strato-cumulus from the southwest. Also the cloud observations at Oklahoma and Springfield, Mo., confirm the hypothesis of an upper drift from the south or southwest. The absence of a marked temperature contrast along the

front $W_1$ is what is generally to be expected in the case of warm fronts and is explained by the combination of several factors. The warm front is generally preceded by winds with increasing southerly components which bring in warmer and warmer air masses. Furthermore, due to surface friction the cold air, as it is pushed away by the warm current, will often leave a thin surface layer behind. This layer will gradually mix with the warmer air above and thus prevent a sudden change in temperature or wind direction at the surface.

There is another element which generally is of great value in determining the position of the fronts, namely, the barometric tendency (the pressure change in the two hours preceding the observation). In the case of the passage of a warm front, preceding which warm air gradually works down to the surface from above, the total weight of the air column over a station decreases, thus causing falling pressure ahead of the front and as a corollary, negative tendencies. In the example such negative tendencies are noted at Pensacola and Springfield, Mo. Little Rock shows a pressure rise of .04 inch in apparent disagreement with the above statement, but this inconsistency is explained by the occurrence of a thunderstorm. After the passage of the warm front, when all the cold air has disappeared, the rate of the pressure fall generally decreases, thus giving an inflection in the pressure curve. As the cold front approaches, the southerly current frequently increases, bringing in warmer air, whereby the pressure is further decreased. This continuous pressure fall will tend to diminish the characteristic angle (A) accompanying the passage of the warm front (see fig. 2), but it will accentuate the angle (B) caused by the passage of the cold front.

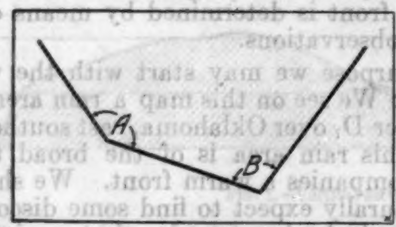



FIG. 2.—Idealized barograph trace during passage of warm sector

As an application of the above idea let us look at the barograph trace at New Orleans (fig. 3). On the morning of the 17th New Orleans was in the cold air with northeast wind, force 3 and a temperature of 58°, while at 8 p. m. the temperature had risen to 70° and the wind changed to south, indicating the passage of the warm front. The cold front seems to have passed during the day of the 18th, the wind having changed from southwest to west and the temperature in the same interval having fallen 2°, as compared to the normal rise of 6° from 8 a. m. to 8 p. m. The barograph trace shows a pressure fall from 6 a. m. to 6 p. m. of the 17th, at which time the warm front apparently passed and the pressure ceased to fall. About 10 a. m. of the 18th the pressure again began to fall, continuing until about 4.30 p. m., when the cold front passed and the pressure began to rise.

If thermograph traces are also available they may be used in the analysis of fronts. However, the effect of the daily range of temperature and the variations due to changes in cloudiness disturb greatly the "dynamic" temperature changes, in other words, the changes produced by advection of air masses from warmer or colder regions.

On map 4 (Feb. 17, p. m.) we have placed the eastern part of the warm front $W_1$ between Jacksonville and Titusville, the reason being that the temperature difference between these stations is 8° while the corresponding difference between Titusville and Miami amounts to only 4° (in spite of the much greater difference in latitude between the two latter). In the same way the temperature difference between Tampa and Apalachicola, which are situated on opposite sides of the front, amounts to 8°. It is seen from the cloud observations at Jacksonville that the warmer air south of the front has begun to slide upward above the $P_1$ air north of the front. The real verification of this construction comes, however, on the next map (map 5), where the front is displaced northward over eastern Georgia and the Carolina coasts, and a wave accompanied by a rain belt has developed along and to the north of the front. Jacksonville has obviously been passed by the front, for the temperature there has risen 4° during the night against a normal fall of 6° and the wind has changed from west to south. It is interesting to note that Jacksonville which, from the beginning, was north of the front and therefore within the region in which the rain belt developed, has had 0.50 inch of precipitation, while Titusville, which all the while

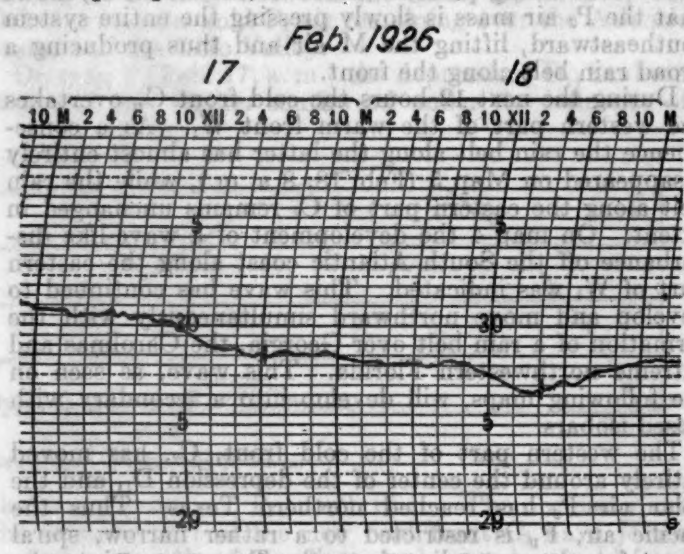



FIG. 3.—Barograph trace at New Orleans, February 17, 18

was in the warm air, got no rain. Also, the temperature at Titusville fell 2° during the night, which is about the amount that usually may be expected, showing that this station remained in the same air mass.

As an example of a cold front let us take the chart 4 of February 17, p. m. The western part of the cold front $C_2$ was determined in the following manner. Since no definite wind shift line could be found, the temperatures were used. The actual temperatures were compared with the normals for the different stations. It was found that all the stations in the $P_2$ air north of $C_2$ had temperatures consistently below the normal. For instance, Santa Fe 28° (normal 36°), Denver 26° (normal 35°), Cheyenne 22° (normal 29°). On the other hand the stations west and south of $C_2$ show temperatures about normal or a little above; for instance, Lander 28° (normal 27°), Grand Junction 38° (normal 37°), Durango 34° (normal 36°), and Roswell 52° (normal 52°). As seen from the above Durango is a little below normal, but the northwesterly wind, the clear sky, and the nonoccurrence of precipitation indicate that the front $C_2$ has not yet passed. It is also seen from the map that all the stations east of the front $C_2$ have cloudy or partly

cloudy weather, while Grand Junction and Durango have clear weather. Furthermore, the greatest positive pressure tendencies are located east of the front. Leadville is obviously situated within the warmer $P_p$ air having a northwest wind that agrees with the general drift within the $P_p$ air mass. This may appear inconsistent with the construction, but when it is considered that this station has an elevation of 3,150 meters, which is about 1,500 meters higher than any other station in this immediate region within the cold sector, the inconsistency disappears for the reason that the $P_2$ current here reaches an elevation between that of Leadville and the surrounding stations.

### III. THE AEROLOGICAL DATA

In the discussion of the aerological maps we have excluded the lower levels (below 1,000 m.) in which the observational data are affected by radiation and local conditions. Maps for the 1 km., 1.5 km., 2 km., and 3 km. levels are reproduced in Figures 4–7. For the kite data entered on these maps altitudes are referred to sea level, and for the pilot balloon data to the ground. The discrepancy thus created is insignificant, since the aerological stations, being all in the Middle West and the East, are generally at small elevations; furthermore, where a kite record was available, the wind data also were taken from this record. Thus all the data at the kite stations are referred to the same base. On the maps for the 17th, we have entered the surface observations at Pueblo (1,420 m.) and at Denver (1,613 m.) on the 1,500 m. map, at Durango (1,991 m.) on the 2,000 m. map and at Leadville (3,150 m.) on the 3,000 m. map.

Starting with the maps of February 16th, 8 a. m., we see that at Ellendale, Drexel, and Broken Arrow temperatures at 1,000 m. are about the same, varying between 2.1° C. at Ellendale and 4.0° C. at Drexel, while over the East the temperature at that level is much lower, being −8.9° C. at Washington, D. C.

This contrast extends up to the highest levels reached by kites.

The eastern and southern boundaries of the cold air ($P_1$) over the Atlantic States are given by the cold front $C_1$ (see map 1).

The body of the $P_1$ air, being limited on the east, south, and west, must therefore be dome shaped. The probable configuration of the transition layer between $P_1$ and the warmer air (M) is indicated by dotted lines for the different levels. The comparatively warm and dry M current will in the subsequent developments serve partly as polar air (in its relations to the warm $T_m$ current from the Gulf appearing on the later maps) and partly as tropical air (relative to the $P_2$ air mass).

Over the West Gulf States a warmer current ($M_1$) is penetrating northward in the 1,000 m. level. Since its relative humidity is low as compared with the warm $T_m$ current appearing on the maps of the 17th, it seems justifiable to assume that this $M_1$ current is of polar origin but during its transport over the Gulf has gradually been heated from below. The probable lateral extension of this $M_1$ air is given by a dotted line.

On account of lack of aerological data in the West, the distribution of the $P_2$, $P_p$ and $T_p$ masses can not be determined, but to aid the reader we have transferred to the 1,000 m. map the positions of the fronts at the surface from map 1.

The morning map of February 17th shows a considerable warming at all levels over Washington, 9.6° C. at 1,000 m., 12.1° C. at 2,000 m., and 13.7° C at 3,000 m., indicating that the $P_1$ air has disappeared, and that Washington is now in the M air. The $M_1$ air, which on the preceding map was over Groesbeck, has been displaced northeastward and is now moving in the form of a spiral towards the center of the depression over Colorado, as indicated by the warm northeast wind at Drexel. At the 1,500 m. level this station has a temperature considerably above that of the M air at the same level, but it has a rather low relative humidity, 51%, whence we may conclude that it can not be within the $T_m$ current from the Gulf, which is characterized by high humidity (87% at Broken Arrow, 81% at Groesbeck).

Both Broken Arrow and Groesbeck show inversions and changes in wind direction at 1,000 m., indicating that the transition layer between $T_m$ and M, at this level passes through the two stations. With increasing height the wind direction in this region becomes southwesterly, the $T_m$ current gradually giving place to a somewhat cooler $T_p$ current. The transition between these two air masses takes place in the layer between 1.5 km. and 2 km., and is characterized by a comparatively high lapse rate (0.54° C. at Broken Arrow; see Sec. IV).

It is interesting to verify our constructions by comparing the temperatures in the M air for the 17th with the corresponding temperatures for the 16th. At the 1,000 m. level we had on the 16th temperatures averaging 3° C. and on the 17th 2° C.; at the 1,500 m. level the temperatures averaged 1° C. and 0° C., respectively, and finally, at the 2,000 m. level −3° C. and −2° C., respectively.

The $P_2$ current has on this map reached Ellendale and brought about a marked cooling.

The maps for February 18th show a considerable displacement of the different air masses. The $P_2$ current has continued to move southward, Drexel as well as Ellendale being now within this air.

The $P_p$ current from the Pacific is moving spirally in towards the center of the LOW, now over eastern Oklahoma. With the arrival of this air the temperatures over Broken Arrow and Groesbeck have fallen. The $M_1$ and the M air masses have been displaced northeastward, and the $T_m$ current has moved eastward. The boundary between the M and the $T_m$ air is found over Due West at the height of 1,200 m., where there is a well marked inversion with wind shift from ESE. to S.

As a verification of the constructions given on the maps we may again compare the temperatures within the different air masses for the 17th and the 18th within the $T_m$ air. We had at the 1.5 km. level on the 17th temperatures averaging +10° C. and on the 18th +9° C.; similarly at the 2 km. level +8° C. and +6° C., respectively. For the $M_1$ air the corresponding data at the 1.5 km. level are +4.3° C. and +5.5° C.; at the 2 km. level +1.2° C. and +2.5° C.

The maps for the 19th show a general spreading southward and eastward of the $P_2$ current, all the kite stations except Due West being now in this current. Due West seems to be within the $M_1$ air which is best seen if the temperatures there are compared with those at Washington for the preceding day. Thus the temperature in the M air on the 18th at Washington was 8.3° C. at the 1,000 meter level, 5.5° C. at 1,500 m. and 2.5° C. at 3,000 m., while the corresponding temperatures at Due West on the 19th were 8.0° C., 5.0° C., and 3.7° C.

### IV. CYCLONIC CONVECTION

A closer study of the warm front rains over the Southern and Central States shows that in one respect they differ widely from the type of warm front rain ordinarily observed in northern and western Europe. In the

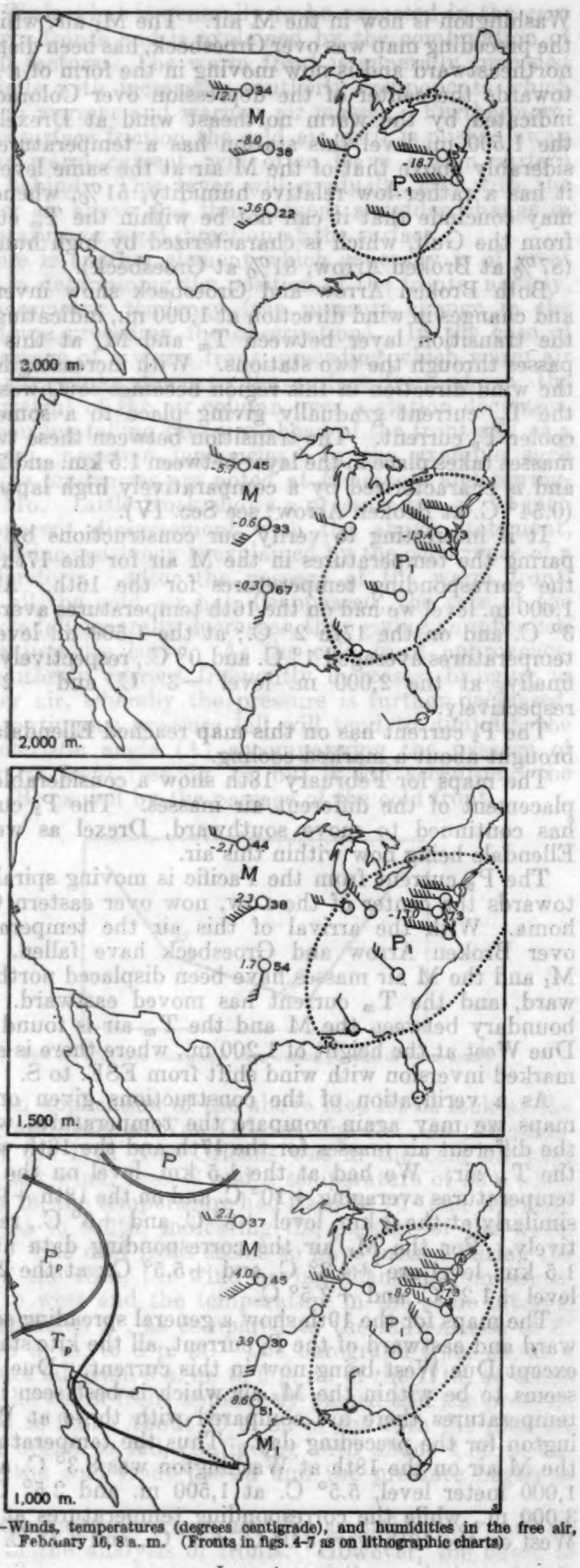



FIG. 4.—Winds, temperatures (degrees centigrade), and humidities in the free air, February 16, 8 a. m. (Fronts in figs. 4–7 as on lithographic charts)

*Inversions*

| Station | Alt. (m.) | Temp. (°C.) | R. H. % | Wind Dir. | Wind Vel. | Alt. (m.) | Temp. (°C.) | R. H. % | Wind Dir. | Wind Vel. |
|---|---|---|---|---|---|---|---|---|---|---|
| Groesbeck | 897 | 7.6 | 50 | sse. | 5.9 | 997 | 8.6 | 51 | ssw. | 2.9 |

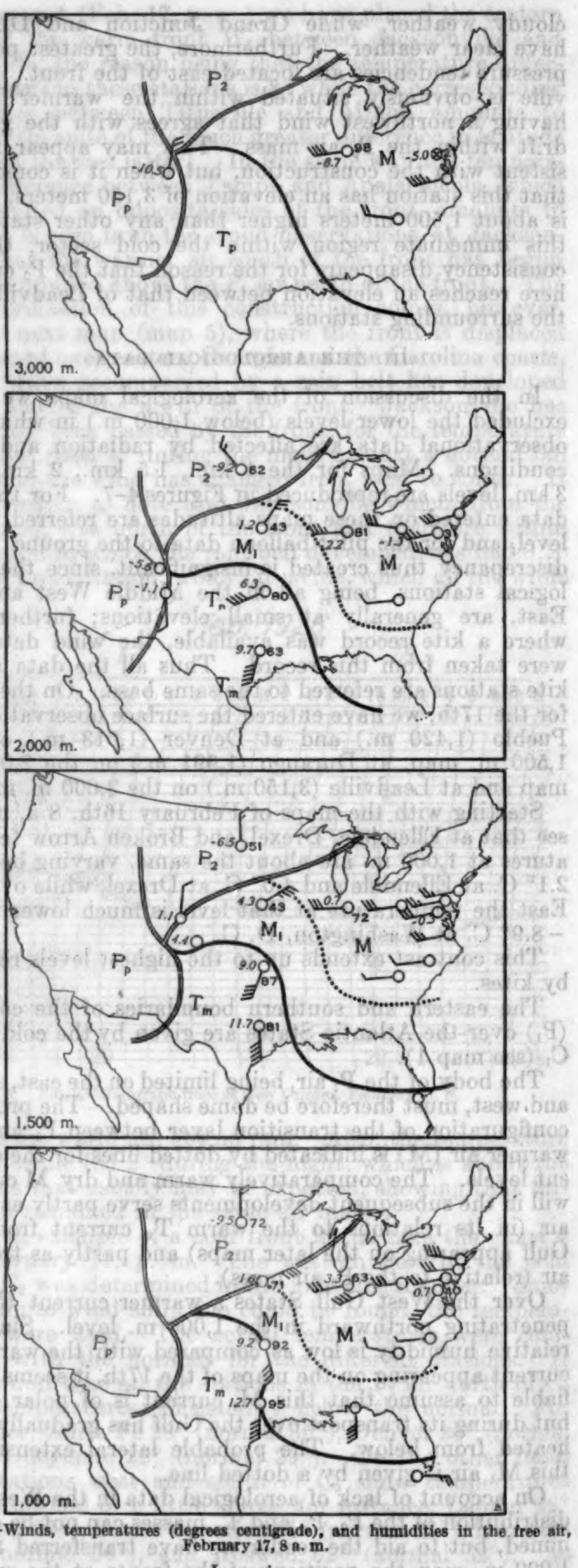



FIG. 5.—Winds, temperatures (degrees centigrade), and humidities in the free air, February 17, 8 a. m.

*Inversions*

| Station | Alt. (m.) | Temp. (°C.) | R. H. % | Wind Dir. | Wind Vel. | Alt. (m.) | Temp. (°C.) | R. H. % | Wind Dir. | Wind Vel. |
|---|---|---|---|---|---|---|---|---|---|---|
| Drexel | 1,040 | 1.5 | 71 | ene. | 15.7 | 1,357 | 5.2 | 43 | ene. | 14.3 |
| Broken Arrow | 894 | 8.4 | 92 | sse. | 16.7 | 1,197 | 10.6 | 91 | s. | 15.8 |
| Groesbeck | 631 | 12.2 | 100 | sse. | 17.7 | 1,180 | 12.9 | 92 | s. | 21.8 |
| Royal Center | 3,100 | −9.4 | 100 | w. | 15.9 | 3,173 | −8.8 | 77 | w. | 19.3 |

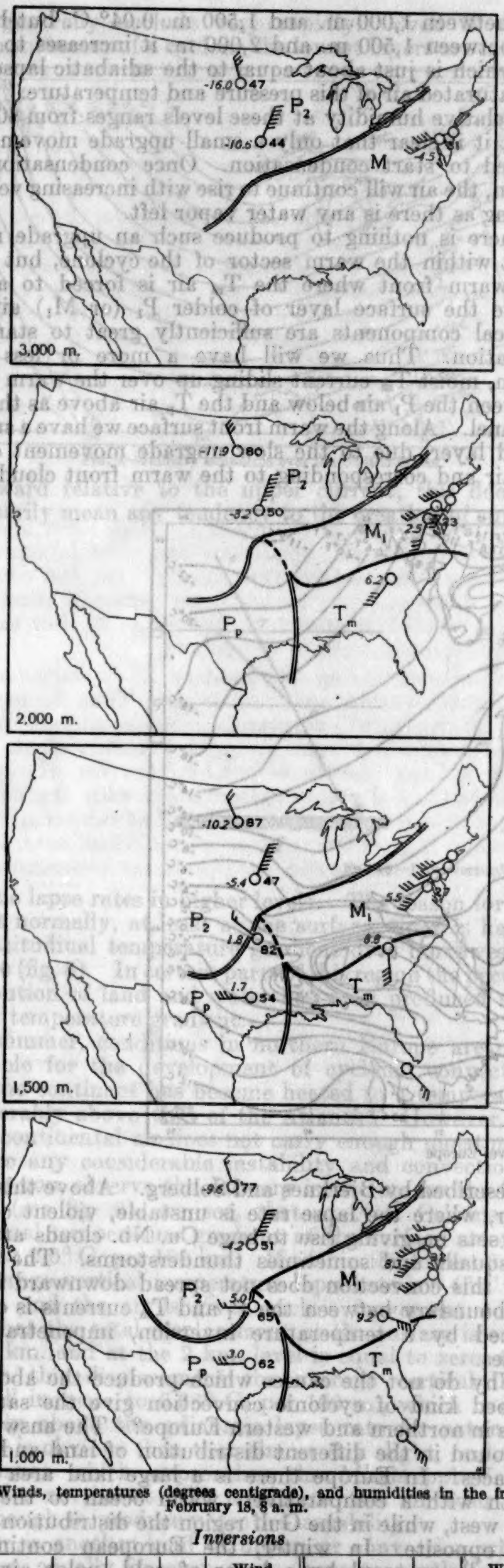



FIG. 6.—Winds, temperatures (degrees centigrade), and humidities in the free air, February 18, 8 a. m.

*Inversions*

| Station | Alt. (m.) | Temp. (°C.) | R. H. % | Wind Dir. | Wind Vel. | Alt. (m.) | Temp. (°C.) | R. H. % | Wind Dir. | Wind Vel. |
|---|---|---|---|---|---|---|---|---|---|---|
| Groesbeck | 1, 337 | 0. 6 | 70 | w. | 11. 7 | 1, 563 | 2. 1 | 48 | w. | 15. 6 |
| Washington | 4, 126 | −14. 0 | 51 | ------ | ------ | 4, 360 | −12. 8 | 65 | ------ | ------ |
| Due West | 1, 149 | 8. 7 | ------ | ese. | 17. 8 | 1, 248 | 11. 1 | ------ | s. | 15. 1 |

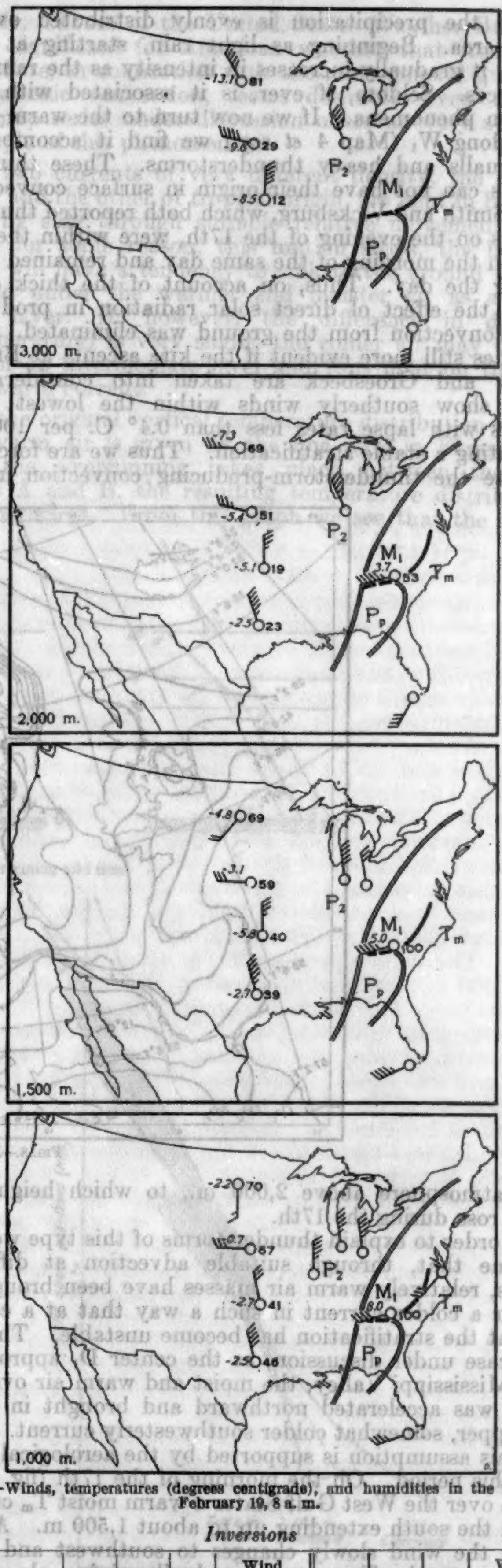



FIG. 7.—Winds, temperatures (degrees centigrade), and humidities in the free air, February 19, 8 a. m.

*Inversions*

| Station | Alt. (m.) | Temp. (°C.) | R. H. % | Wind Dir. | Wind Vel. | Alt. (m.) | Temp. (°C) | R. H % | Wind Dir. | Wind Vel. |
|---|---|---|---|---|---|---|---|---|---|---|
| Broken Arrow | 1, 558 | −6. 2 | 40 | n. | 13. 5 | 1, 701 | −4. 2 | 22 | n. | 13. 2 |
| Groesbeck | 1, 252 | −3. 2 | 45 | nnw. | 20. 8 | 1, 792 | −2. 2 | 31 | nnw. | 21. 7 |
| Due West | 2, 018 | 3. 7 | 50 | wsw. | 18. 9 | 2, 186 | 5. 2 | 32 | wsw. | 24. 8 |

latter, the precipitation is evenly distributed over a large area. Beginning as light rain, starting at high levels, it gradually increases in intensity as the rain belt advances. Seldom, if ever, is it associated with convection phenomena. If we now turn to the warm front rain along $W_1$ (Map 4 *et seq.*) we find it accompanied by squalls and heavy thunderstorms. These thunderstorms can not have their origin in surface convection. Fort Smith and Vicksburg, which both reported thunderstorms on the evening of the 17th, were within the rain belt on the morning of the same day and remained there during the day. Thus, on account of the thick cloud layer, the effect of direct solar radiation in producing heat convection from the ground was eliminated. This becomes still more evident if the kite ascents at Broken Arrow and Groesbeck are taken into consideration. They show southerly winds within the lowest 1,500 meters with lapse rates less than 0.4° C. per 100 m., indicating a stable stratification. Thus we are forced to localize the thunderstorm-producing convection in the free atmosphere above 2,000 m., to which height the kites rose during the 17th.

In order to explain thunderstorms of this type we may assume that, through suitable advection at different levels, relatively warm air masses have been brought in under a colder current in such a way that at a certain height the stratification has become unstable. Thus, in the case under discussion, as the center $D_1$ approached the Mississippi Valley, the moist and warm air over the Gulf was accelerated northward and brought in below an upper, somewhat colder southwesterly current.

This assumption is supported by the aerological maps for this period. On the morning of the 17th (fig. 5) we have over the West Gulf States a warm moist $T_m$ current from the south extending up to about 1,500 m. At this level the wind slowly changes to southwest and west-southwest, the $T_m$ current gradually giving place to a somewhat colder $T_p$ current. At the same time the vertical temperature fall becomes steeper. Between 500 m. and 1,000 m. the lapse rate is only 0.18° C. per 100 m. and between 1,000 m. and 1,500 m. 0.04° C. but higher up, between 1,500 m. and 2,000 m. it increases to 0.54° C., which is just about equal to the adiabatic lapse rate for saturated air of this pressure and temperature. Since the relative humidity at these levels ranges from 80% to 87%, it is clear that only a small upgrade movement is needed to start condensation. Once condensation has begun, the air will continue to rise with increasing velocity as long as there is any water vapor left.

There is nothing to produce such an upgrade movement within the warm sector of the cyclone, but along the warm front where the $T_m$ air is forced to ascend above the surface layer of colder $P_1$ (or $M_1$) air, the vertical components are sufficiently great to start condensation. Thus we will have a more or less thin, warm, moist $T_m$ current sliding up over the warm front, between the $P_1$ air below and the $T_p$ air above as through a funnel. Along the warm front surface we have a smooth cloud layer, due to the slow upgrade movement of the $T_m$ air and corresponding to the warm front cloud layer as described by Bjerknes and Solberg. Above this cloud layer, where the lapse rate is unstable, violent convection sets in, giving rise to huge Cu. Nb. clouds attended by squalls and sometimes thunderstorms. The reason why this convection does not spread downward is that the boundary between the $P_1$ and $T_m$ currents is characterized by a temperature inversion, impenetrable by eddies.

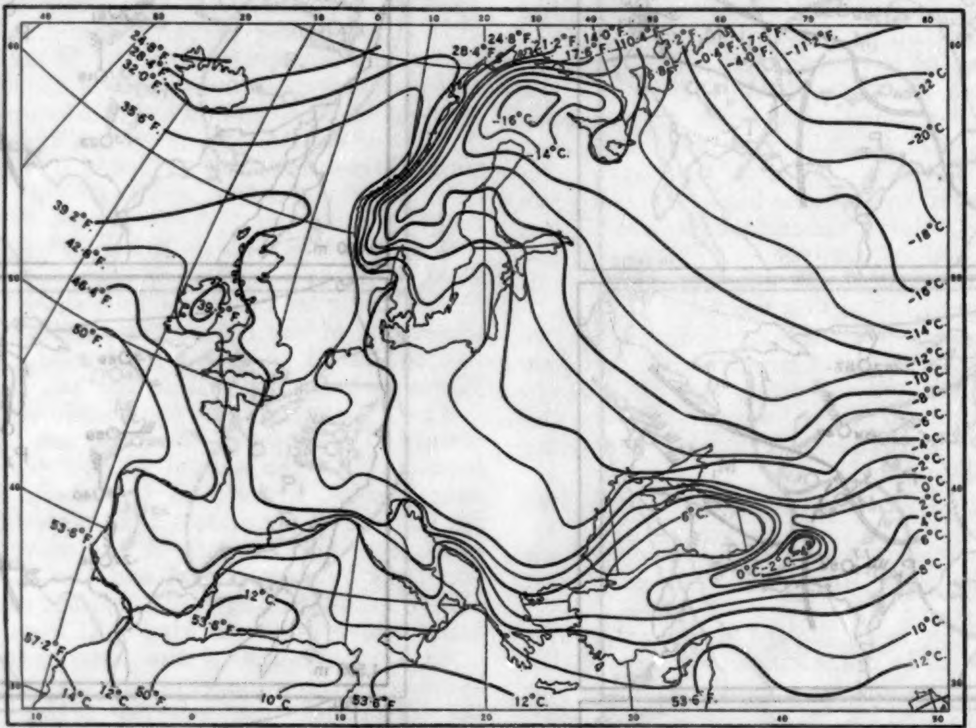


FIG. 8.—January isotherms over Europe

Why do not the causes which produce the above described kind of cyclonic convection give the same results in northern and western Europe? The answer is to be found in the different distribution of land and water surfaces. In Europe there is a large land area in the south with a comparatively warm ocean to the north and west, while in the Gulf region the distribution is just the opposite. In winter, the European continent is generally covered by a layer of cold, polar air. The cyclones, which move northeastward along the coast, generally have the form of long narrow tongues of warm air pointing northeastward. On account of this form

they generally occlude very rapidly. Even if within the warm sector of a cyclone the lowest layers are moving

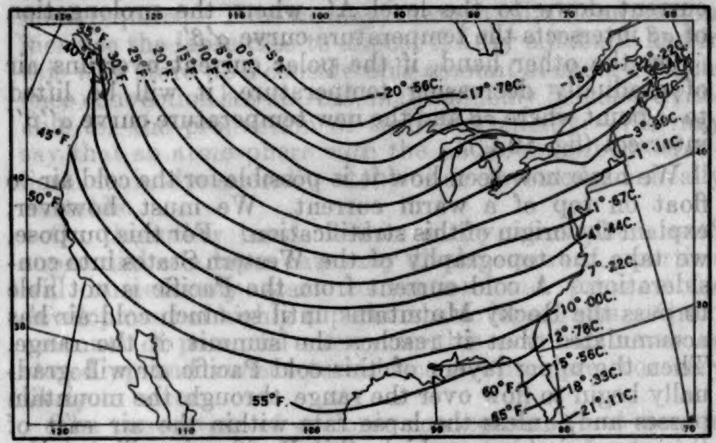


FIG. 9.—January isotherms over the United States

northward relative to the upper current, this does not necessarily mean any tendency to the creation of supera-

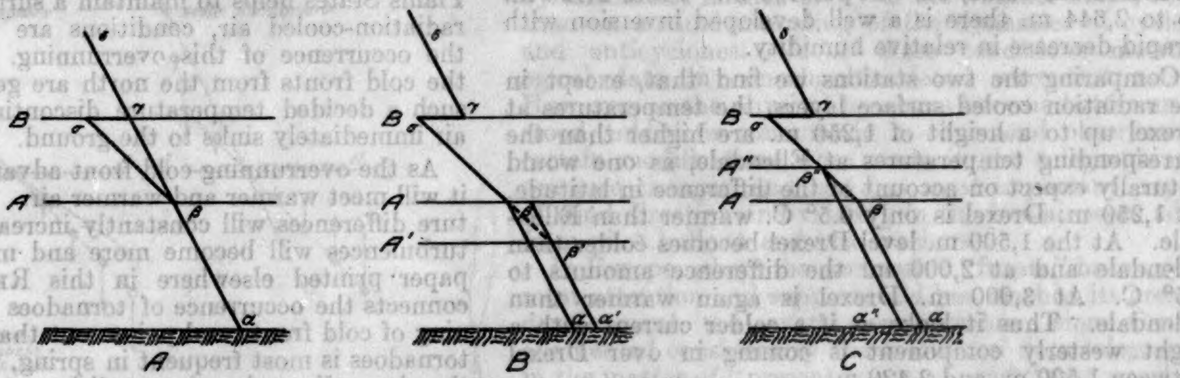



FIG. 10.—Ideal vertical distribution in overrunning cold front

diabatic lapse rates in higher levels. The reason for this is that normally, at least at the surface, there is hardly any latitudinal temperature gradient over northwestern Europe (fig. 8). In certain parts of this region the peculiar distribution of land and water has even produced a reversed temperature gradient.

In summer, conditions in northern Europe are more favorable for the development of cyclonic convection, since the continent has become heated to a temperature considerably above that of the Atlantic. However, the warm continental air does not carry enough moisture to produce any considerable instability and convection.

If we now observe the January isotherms for the Gulf States (see fig. 9), we see, that at New Orleans the latitudinal temperature gradient at the surface amounts to about 2.6° C. per 100 km. If within the lowest 2 km. the average vertical temperature lapse rate is 0.4° C. per 100 m. and the air is given such a movement northward that the total displacement at the surface is equal to 200 km. and at the 2 km. level is equal to zero, then through this displacement the average vertical lapse rate will increase to 0.66° C. per 100 m., which is considerably above the adiabatic lapse rate for saturated air. It is obvious then that almost any slight, occluded disturbance which approaches the Mississippi Valley from the northwest will accelerate the air over the Gulf enough to produce potential instability.

There is another kind of upper air convection which plays an equally or even more important rôle in the United States, namely, that caused by the passage in higher levels of a cold front over a warmer surface current. This type of convection, the importance of which has often been emphasized (though not in print) by Mr. Choate of the United States Weather Bureau,[3] is so significant for American weather that treatment of it here, in connection with the more general question of cyclonic convection, seems desirable, even though the map series under discussion offers no very striking example of this phenomenon.

If two currents of very different density, the one of polar and the other of tropical origin, are kept in balance side by side through suitable relative movements and then, for some reason, this motion stops, the heavier mass will have a tendency to sink to the ground and to spread under the warmer and moister air as a thin, cold layer. If, however, the difference in density (temperature) is very slight, the colder air may spread out in an intermediate level and thus float on the top of a warm current.

If the original vertical temperature distribution within the warm air is given by the line $\alpha\beta\gamma\delta$ in Figure 10A and the overrunning takes place between the two levels A and B, the resulting temperature distribution will be $\alpha\beta\sigma\gamma\delta$. From this graph we see that the upper

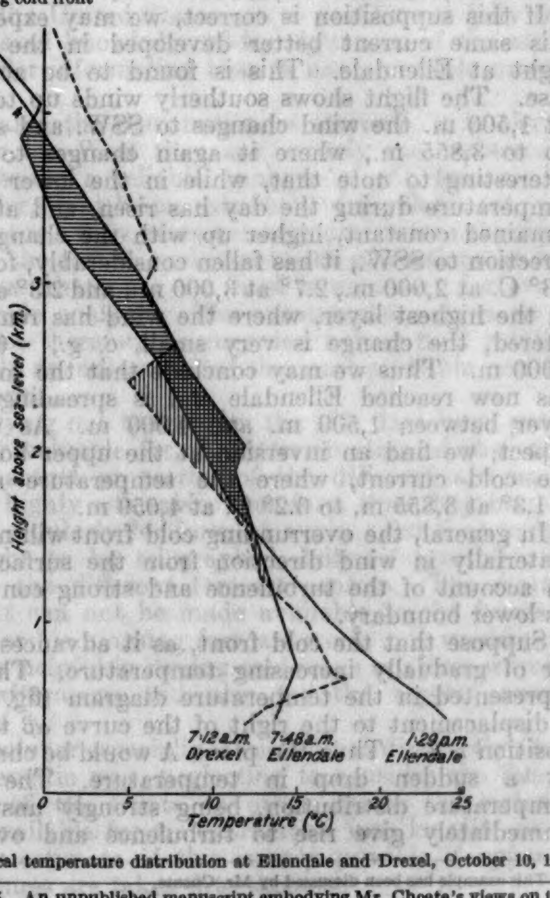



FIG. 11.—Vertical temperature distribution at Ellendale and Drexel, October 10, 1923

[3] See page 495. An unpublished manuscript embodying Mr. Choate's views on this subject is on file in the Weather Bureau at Washington.

boundary of the cold current is now characterized by an inversion and increased stability. In the lower levels, where the polar current is in contact with the underlying moist air, the stability has decreased or even changed into instability; as a consequence, convection is likely to occur.

A good example of this overrunning is found in the kite ascents at Drexel and Ellendale for October 10, 1923, Figure 11.[4] On the morning of this day both stations, which are situated on the eastern side of a trough, have surface winds from SSE. At Ellendale, the wind between 1,250 m. and 1,500 m. turns to south and remains south up to the top of the flight, 4,300 m. The relative humidity decreases gradually to 27% from the surface up to 3,200 m. and then slowly rises to 73% at 4,300 m. There is a surface inversion and a weak inversion at the 2,000 m. level, the lapse rate being small at all heights. At Drexel, the wind between 1,250 m. and 1,500 m. turns from S. to SSW., while the temperature lapse rate increases. Between 1,564 m. and 2,000 m. the wind again backs to S. In this layer the lapse rate reaches its maximum value, 0.8° C. per 100 m. From 2,420 m. up to 2,644 m. there is a well developed inversion with a rapid decrease in relative humidity.

Comparing the two stations we find that, except in the radiation cooled surface layers, the temperatures at Drexel up to a height of 1,250 m. are higher than the corresponding temperatures at Ellendale, as one would naturally expect on account of the difference in latitude. At 1,250 m. Drexel is only 0.5° C. warmer than Ellendale. At the 1,500 m. level Drexel becomes colder than Ellendale and at 2,000 m. the difference amounts to 3.5° C. At 3,000 m. Drexel is again warmer than Ellendale. Thus it looks as if a colder current with a slight westerly component is coming in over Drexel between 1,500 m. and 2,420 m.

If this supposition is correct, we may expect to find this same current better developed in the afternoon flight at Ellendale. This is found to be actually the case. The flight shows southerly winds up to 1,250 m. At 1,500 m. the wind changes to SSW. and so remains up to 3,855 m., where it again changes to S. It is interesting to note that, while in the lower levels the temperature during the day has risen, and at 1,500 m. remained constant, higher up with the change in wind direction to SSW., it has fallen considerably, for instance 2.3° C. at 2,000 m., 2.7° at 3,000 m., and 2.3° at 3,500 m. In the highest layer, where the wind has remained unaltered, the change is very small, e. g., −0.3° C. at 4,000 m. Thus we may conclude that the cold current has now reached Ellendale and is spreading out in a layer between 1,500 m. and 4,000 m. As we should expect, we find an inversion at the upper boundary of the cold current, where the temperature rises from −1.3° at 3,855 m. to 0.2° C. at 4,059 m.

In general, the overrunning cold front will not deviate materially in wind direction from the surface current, on account of the turbulence and strong convection at its lower boundary.

Suppose that the cold front, as it advances, overruns air of gradually increasing temperature. This can be represented in the temperature diagram (fig. 10 B) by a displacement to the right of the curve $\alpha\beta$ to the new position $\alpha'\beta'$. Thus the plane A would be characterized by a sudden drop in temperature. The resulting temperature distribution, being strongly unstable, will immediately give rise to turbulence and overturning.

[4] This example has been discussed by Mr. Choate.

As a consequence, the two air masses will mix to some extent but the main result will be a sinking of the polar current down to the level A′, where the prolongation of $\sigma\beta$ intersects the temperature curve $\alpha'\beta'$.

On the other hand, if the polar current overruns air of gradually decreasing temperature, it will be lifted to a point where $\sigma\beta$ and the new temperature curve $\alpha''\beta''$ intersect (fig. 10 C).

We have now seen how it is possible for the cold air to float on top of a warm current. We must, however, explain the origin of this stratification. For this purpose, we take the topography of the Western States into consideration. A cold current from the Pacific is not able to pass the Rocky Mountains until so much cold air has accumulated that it reaches the summit of the range. Then the upper layers of this cold Pacific air will gradually begin to flow over the range through the mountain passes and, unless the lapse rate within the air east of the mountains is very high, this Pacific air will not immediately penetrate down to the surface. In spring, when the snow cover on the ground in the Northern Plains States helps to maintain a surface layer of stable, radiation-cooled air, conditions are very favorable for the occurrence of this overrunning. On the contrary, the cold fronts from the north are generally marked by such a decided temperature discontinuity that the cold air immediately sinks to the ground.

As the overrunning cold front advances southeastward it will meet warmer and warmer air. Thus the temperature differences will constantly increase and the free air turbulences will become more and more violent. In a paper printed elsewhere in this REVIEW, Humphreys connects the occurrence of tornadoes with the overrunning of cold fronts and points out that the occurrence of tornadoes is most frequent in spring, when according to the above discussion the conditions for overrunning are most favorable.

It would seem that overrunning should also be possible in northwestern Europe. However, in winter time a mid-air cold front which approaches the European continent from the relatively warm ocean to the northwest, will meet colder and colder air and thus be lifted to higher levels, becoming gradually weaker. In summer time, when the continent is heated, the reverse is true but the continental air is then rather dry, which will counteract the tendency to convection.

Thus we are led back to the question: What is the role of the moisture in the atmosphere and especially, what is the significance of the lapse rate for saturated air? The chief difference between convection in moist air and in dry is this: An atmosphere in which the lapse rate is a little steeper than the moist adiabatic (without reaching the dry adiabatic), and in which the humidity is a little less than 100%, is stable from a purely dynamical point of view. An air particle (fig. 12), which is lifted from its equilibrium position, will expand at first according to the dry adiabatic law, will become colder and heavier than its surroundings and hence will tend to sink to its original position. If the upward displacement is great enough, the water vapor will condense and the temperature change will now follow a psuedo-adiabatic curve. Only, when the forced displacement of the particle is so great that the particle, moving along this pseudo-adiabatic curve, again meets the curve for the actual temperature distribution, will instability result. Thus we see that in an atmosphere where the lapse rate is intermediate between the moist adiabatic and the dry adiabatic and where the humidity is less than 100%, a

finite displacement is necessary in order to start convection and the less the humidity the greater the displacement required. Thus we may, through suitable advection, increase the lapse rate to almost the dry adiabatic and in this way store up a considerable amount of energy which, once convection has started, may suddenly be made available for the production of turbulent energy. We may say that an atmosphere with the above-described stratification is dynamically stable but thermodynamically unstable.

On the other hand, within a dry atmosphere with superadiabatic lapse rate, any displacement of a particle will immediately start convection and prevent the development of highly superadiabatic lapse rates. Great amounts of potential energy in this case can never be stored up and violent turbulence is, therefore, not very likely to occur.

The conception of cyclonic convection is not new in American meteorology but can be traced as far back as

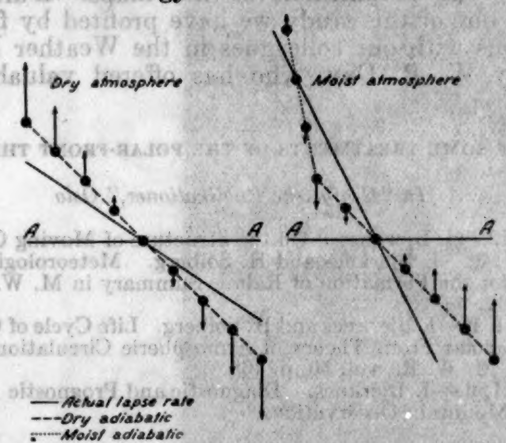



FIG. 12.—Instability in a dry and in a moist atmosphere. Length of arrows is proportional to the force acting on a particle which has been displaced from its equilibrium position in the plane AA

Ferrel's condensation theory. In later years the idea of convection arising from instability produced by suitable relative movements of superposed air layers was used by Humphreys,[5] to explain the thunderstorms that frequently occur in the southern quadrants of a LOW. Here, according to Humphreys the upper winds are westerly while in the surface layers, on account of friction with the ground, the wind has a southerly component. As a consequence of this wind distribution warmer and warmer air is brought in below, instablilty results and convection starts. Mr. Choate, through his studies of kite records at Drexel and other stations, has been led to the conclusion that a large percentage of the cyclonic rainfall must be attributed to convection which begins at some distance above the ground, due to relative movements of superposed air layers. As pointed out above he has specially emphasized the frequent occurrence of overrunning cold fronts.

## V. CONCLUSION

The present distribution of meteorological stations in the United States has been brought about as a very gradual development by the addition of a few stations at a time. The weather map of January 1, 1871, shows that of the 29 stations reporting by telegraph, 11 were along the Gulf and Atlantic coast, 8 along the Lakes and 10 in the interior. Of the latter 10, only 2 were west of the Mississippi River. During the next 10 years the number had increased to 91 and in the following decade to 128. By 1900 there were 139, by 1910, 168 and at present between 180 and 190. At first the determining factor in the establishment of stations was the location of the Signal Corps stations, where telegraph facilities and observers were available and the further fact that the service was inaugurated to protect shipping primarily. Later, when telegraph lines tapped almost every region, the need of serving important industrial and agricultural communities provided the moving reason. Naturally the eastern half of the country had more stations than the West.

The data telegraphed depended first on the needs of the forecasters, supplemented later by demands for publication in the press and on the weather maps and bulletins of certain of the data, limited continually by need for economy in telegraphing.

The groundwork of reports was organized at a time when little was known of forecasting, and the system of reports was later expanded during a period when forecasting was based on the experience accumulated by forecasters in their study of the weather maps, rather than on an understanding of the dynamics of cyclones and anticyclones. Under these conditions meteorological data in considerable detail were not needed. However, as the physical processes became better understood, additions were made in the cloud observations, certain modifications were made in the telegraphing of pressure changes, and last but most important, reports of wind direction and velocity in the free air were added from pilot balloon and kite stations.

In Europe, where the doctrine of "fronts" has received most attention and support, and has reached its greatest development, the several countries have since the war augmented considerably the amount of data telegraphed in the matter of "present weather" and "past weather." If we in the United States are to profit most fully from our increased knowledge of the dynamics of the atmosphere, fuller information than is now available must be secured.

As regards the distribution of stations, it is obvious that over the West they are entirely too scattered to make possible a reliable analysis of the fronts. The topography, which is extremely irregular, not only affects but in many cases actually determines the movements of the fronts, and a network of stations at least as dense as that over the East is necessary for even a rather crude analysis. The constructions given on our maps must therefore be regarded not as final solutions but merely as indications of the most probable positions of the fronts.

In carrying out this study, the kite data have proved extremely valuable for the determination of the extent and the actual properties of the different air masses. It seems highly advisable, therefore, that they be made available regularly for forecast work. For that purpose they ought to be telegraphed daily, if possible twice daily, to the different forecast centers. The morning kite flight can not be made available to the forecaster in time for his morning forecast work, but would prove extremely helpful in issuing cold wave or storm warnings in the afternoon, and also for the regular evening forecasts.

The beginner especially is very apt to discuss the fronts in a schematic way, neglecting to consider the relative strength of the fronts, in other words, the potential energy available for transformation into kinetic energy. A proper estimate of this is only possible if upper air temperatures are taken into account.

[5] Physics of the Air, Philadelphia, 1920, p. 347.

Furthermore, in the forecasting of cyclonic convection of the kind described in Section IV, the use of kite data is almost indispensable. A kite flight from Groesbeck or Broken Arrow, combined with a few pilot balloon runs and surface data from the Gulf region, can tell how much of a relative displacement of the different air layers is necessary to produce instability and free air convection.

The surface observations in the United States are not so detailed as in Europe where, since the war, forecasting methods in practically all countries demand very specific and detailed information. In the United States the time interval between consecutive maps is 12 hours, which is too long, especially in the case of rapid developments and rapid movements. An intermediate pressure map, say at 2 p. m., would be of much assistance.

The element which has perhaps proved most valuable in tracing the fronts is the barometric tendency or the pressure change in the 2 (in Europe 3) hours preceding the observation. According to the new international code now used in Europe this element is given by two figures, the first (the characteristic) giving a description of the general form of the pressure curve (for instance, first falling, then stationary), while the second gives the total amount of the pressure change. The "characteristic" has proved of great value for the determination of the exact positions of the fronts since, as pointed out in Section II, the warm and cold fronts generally are associated with typical forms of pressure curves (cold front: first falling or stationary, then rising; and warm front: first falling, then stationary). The necessity of introducing the characteristic on the American weather maps as one of the principal elements can therefore not be too strongly emphasized. According to the system now in use in the United States, pressure changes smaller than 0.04 inch are not telegraphed. It is suggested that this limit be lowered to 0.02 inch since the characteristic tendencies accompanying weak or occluded fronts are generally very small.

The weather at the time of observation is according to the new international code given by two numbers, making it possible to distinguish between 100 different types of weather. A closer study of synoptic maps soon shows that the different fronts and sections of the cyclones are characterized by very well-defined weather types as a rule. This elaborate scale has therefore become a very important instrument in the analysis. Doubtless the five classifications now in use in the United States are entirely too few to meet the demands of the situation, although we should not necessarily suggest an increase to 100. Also some information concerning the weather between the observations would be of very great value.

It is believed that the above study has furnished conclusive evidence that the polar front theory can be applied with great advantage to even rather complicated weather maps in the United States and that it enables us to explain phenomena which without a knowledge of the dynamics of the situation would hardly be understood. For instance, the rapid dissolution of the rain belt over southern Washington and northwestern Idaho on Map 1 as well as the corresponding disappearance of the rain belt on Map 4 over Oklahoma, Arkansas, and Mississippi can only be explained as the effects of occlusion, a conception which in itself is a product of the polar front theory.

It is not to be expected that a detailed analysis could be made of every map in the actual forecast work. However, a discriminating study of a number of typical weather situations, distinguishing the significant features of these types from the incidental, would probably enable the meteorologist to recognize these types after a brief survey of any map. For that purpose the improvements in observational data pointed out above seem to be necessary.

ACKNOWLEDGMENT

It is a pleasure to acknowledge the valuable assistance which H. C. Willett of the Forecast Division has rendered in the preparation of the maps. During the carrying out of this study we have profited by frequent discussions with our colleagues in the Weather Bureau, especially W. P. Day, who has offered valuable suggestions.

LIST OF SOME TREATMENTS OF THE POLAR-FRONT THEORY

*A. In "Geofysiske Publikationer," Oslo*

Volume I, 2.—J. Bjerknes. On the Structure of Moving Cyclones.
Volume II, 3.—J. Bjerknes and H. Solberg. Meteorological Conditions for the Formation of Rain. Summary in M. W. R., vol. 50, p. 402.
Volume III, 1.—J. Bjerknes and H. Solberg. Life Cycle of Cyclones and the Polar Front Theory of Atmospheric Circulation. Summary in M. W. R., vol. 50, p. 468.
Volume III, 6.—J. Bjerknes. Diagnostic and Prognostic Application of Mountain Observations.

*B. In "Quarterly Journal of the Royal Meteorological Society," London*

Volume 46.—V. Bjerknes. The Structure of the Atmosphere when Rain is Falling.

*C. In the Monthly Weather Review, Washington*

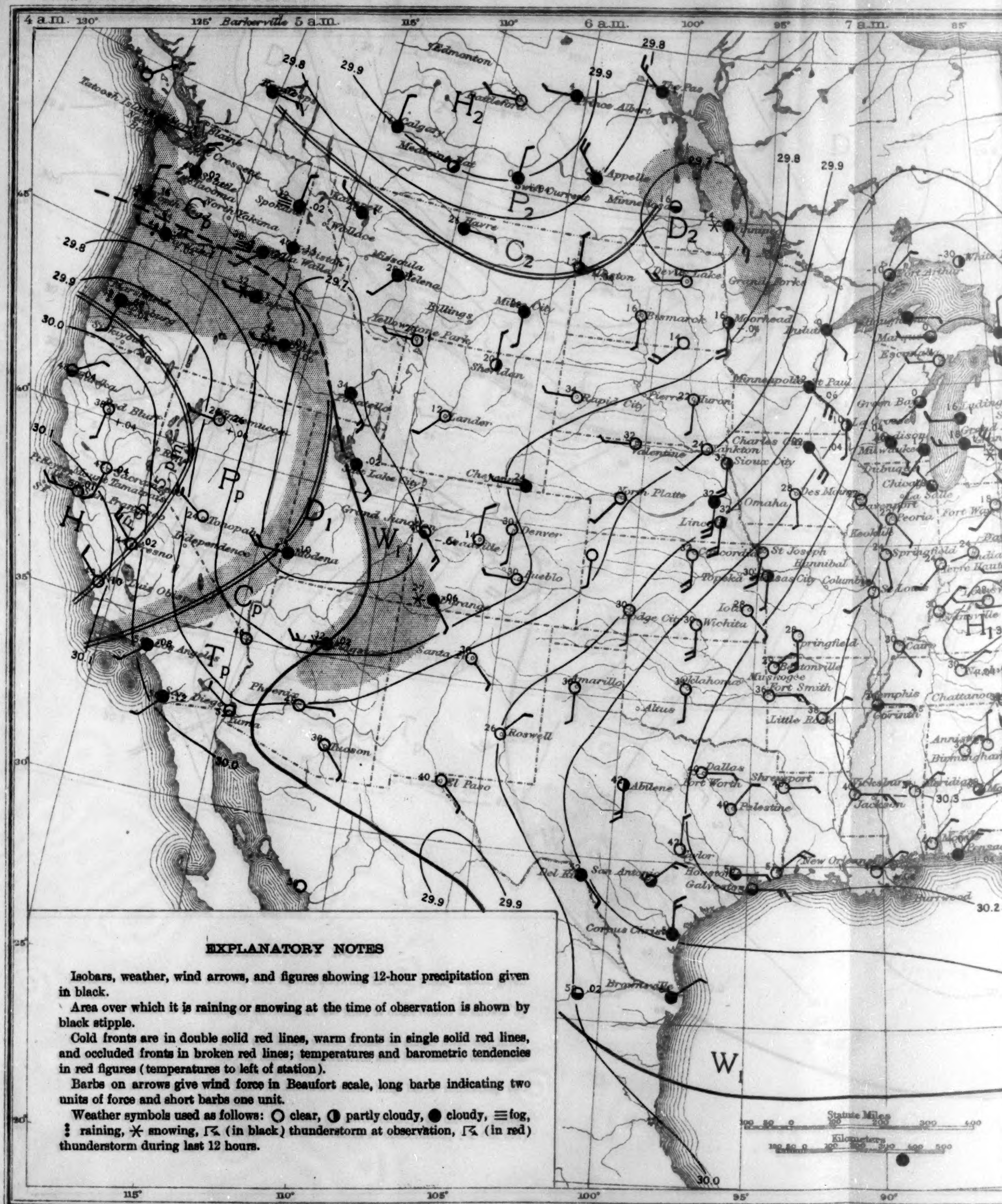
Volume 47, No. 2.—V. Bjerknes. Weather Forecasting.
J. Bjerknes. On the Structure of Moving Cyclones.
Volume 49, No. 1.—V. Bjerknes. The Meteorology of the Temperate Zone and the General Atmospheric Circulation.
Volume 52, No. 11.—J. Bjerknes and M. A. Giblett. An Analysis of a Retrograde Depression in the Eastern United States of America.
Volume 53, No. 9.—R. H. Weightman. Some Observations on the Cyclonic Precipitation of February 22–23, 1925, in the Central and Eastern United States.

In addition the two following papers in German should also be included in this list. The first gives a summary of the polar front theory and the arguments for and against it, while the second contains an application of the theory to a series of European weather maps.

H. Ficker: Polar-front, Aufbau, Entstehung und Lebensgeschichte der Zyklonen. Met. Zeitschrift, March, 1923.

T. Bergeron and G. Swoboda: Wellen und Wirbel an einer Quasistationären Grenzfläche über Europa, Veröffentlichungen des geophysikalischen Instituts der Universität Leipzig, Bd. III, Heft 2. (See review by H. Willett, Mo. Wea. Rev., Nov., 1926.)

February 16, 8 a. m. C.-G. B. & R. H. W.




## EXPLANATORY NOTES

Isobars, weather, wind arrows, and figures showing 12-hour precipitation given in black.

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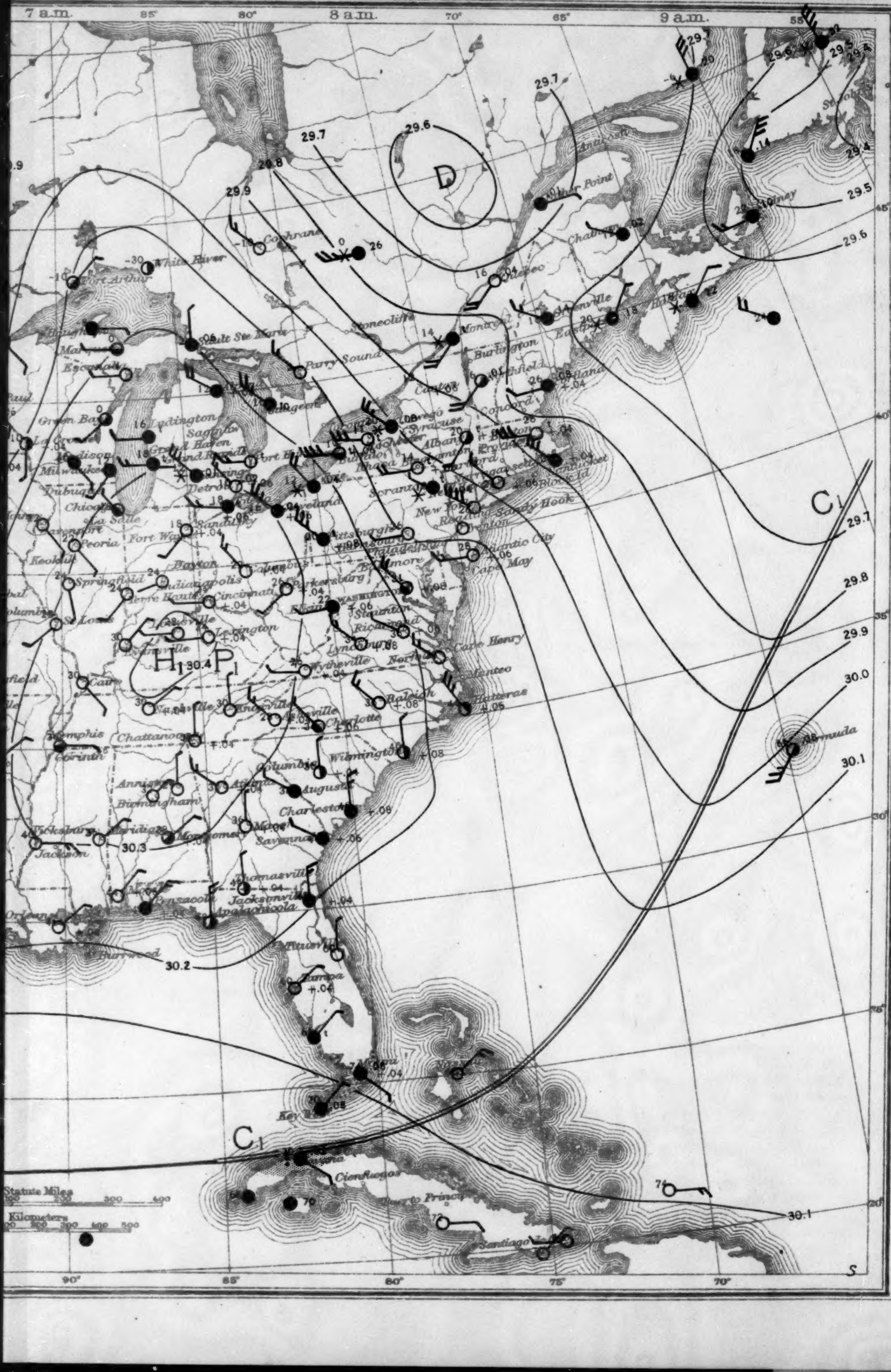
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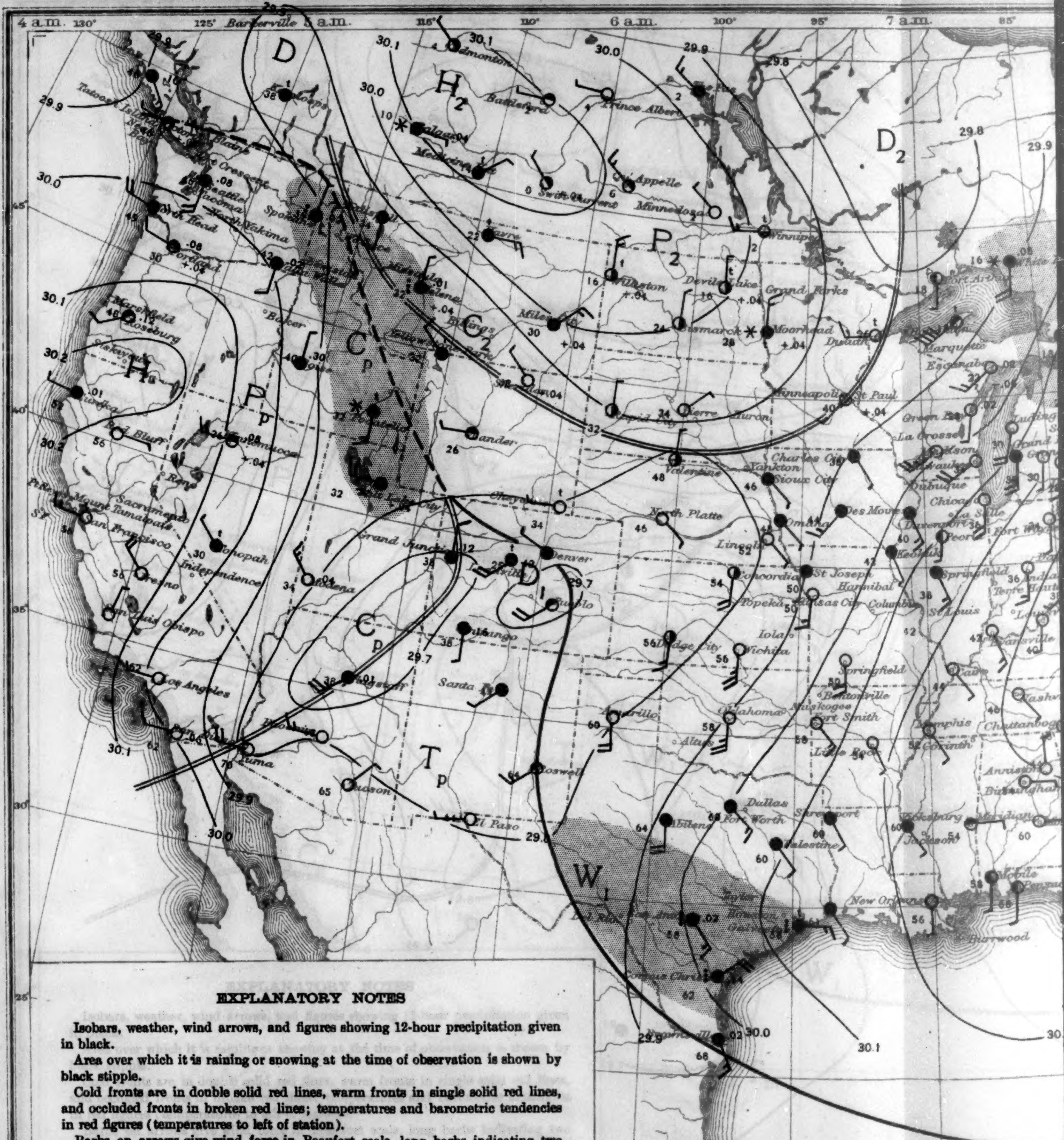
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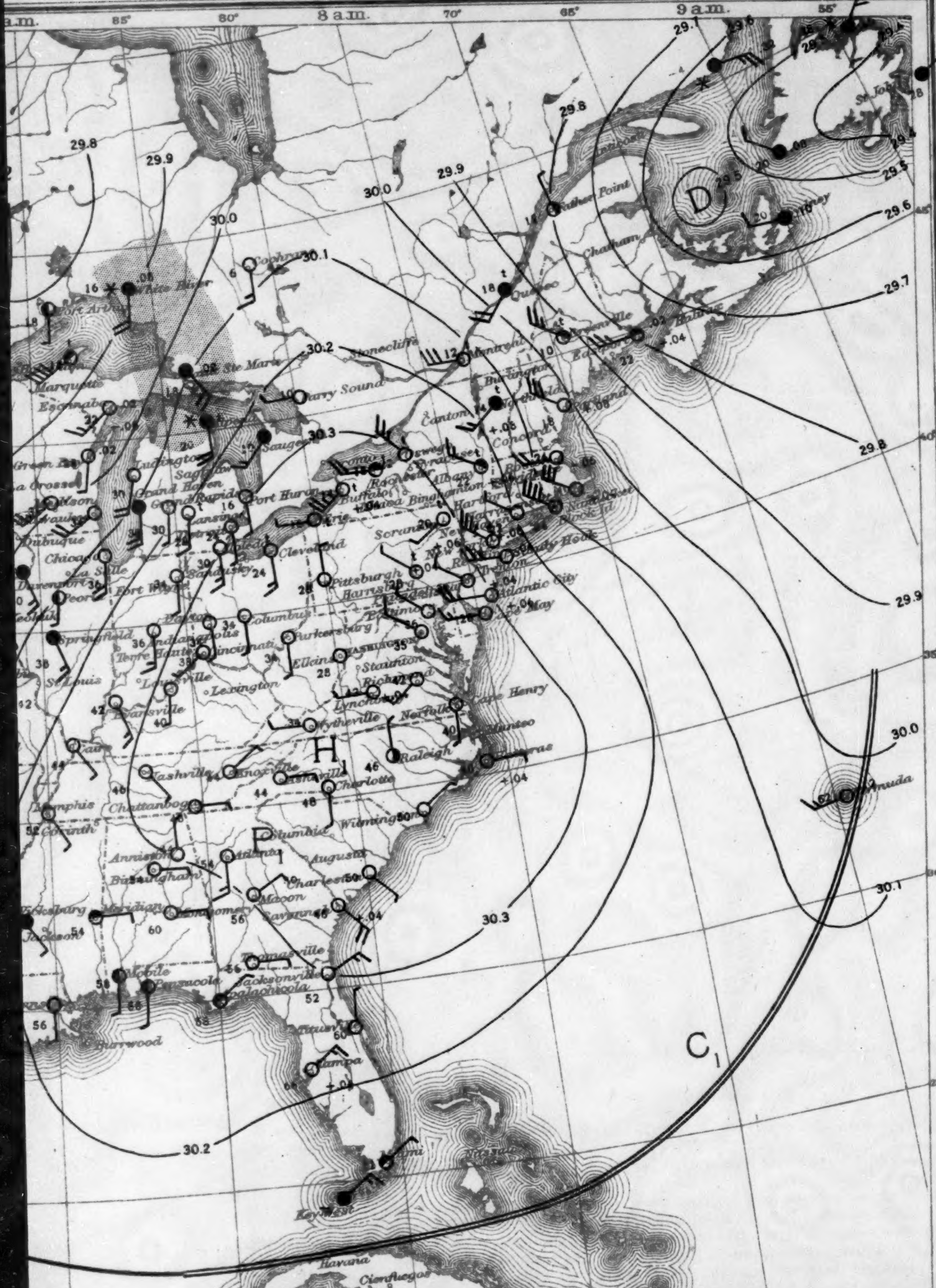
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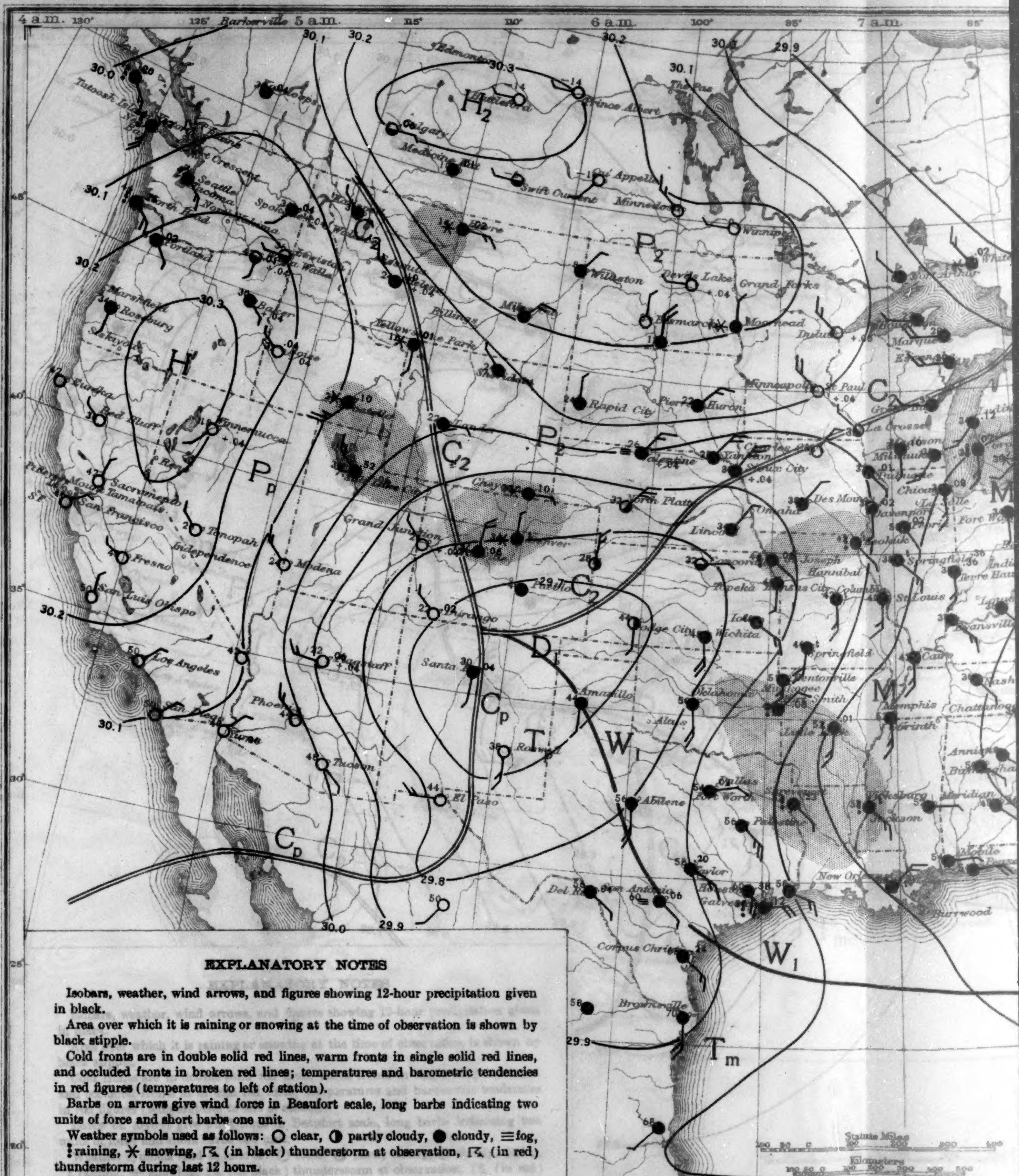


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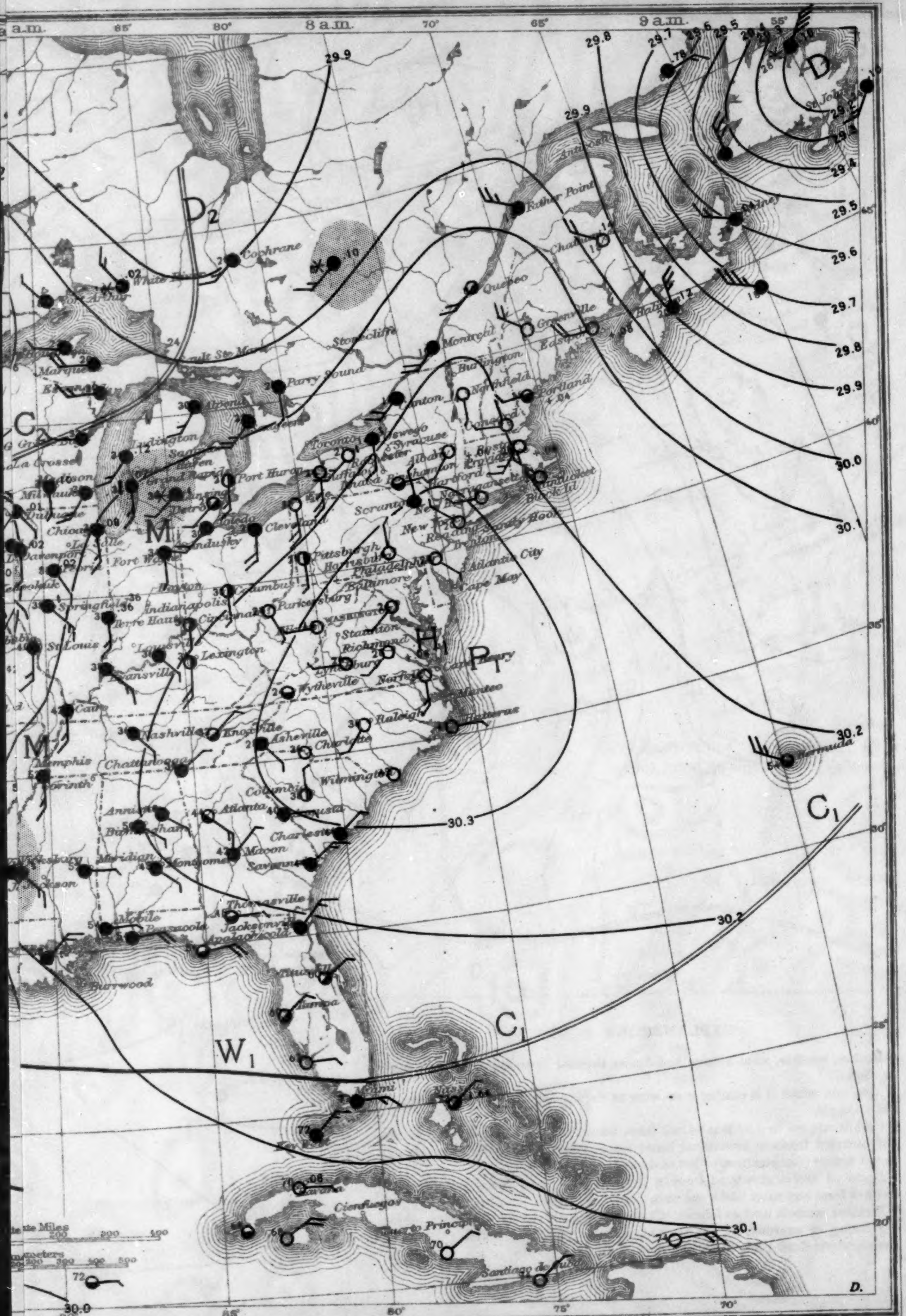
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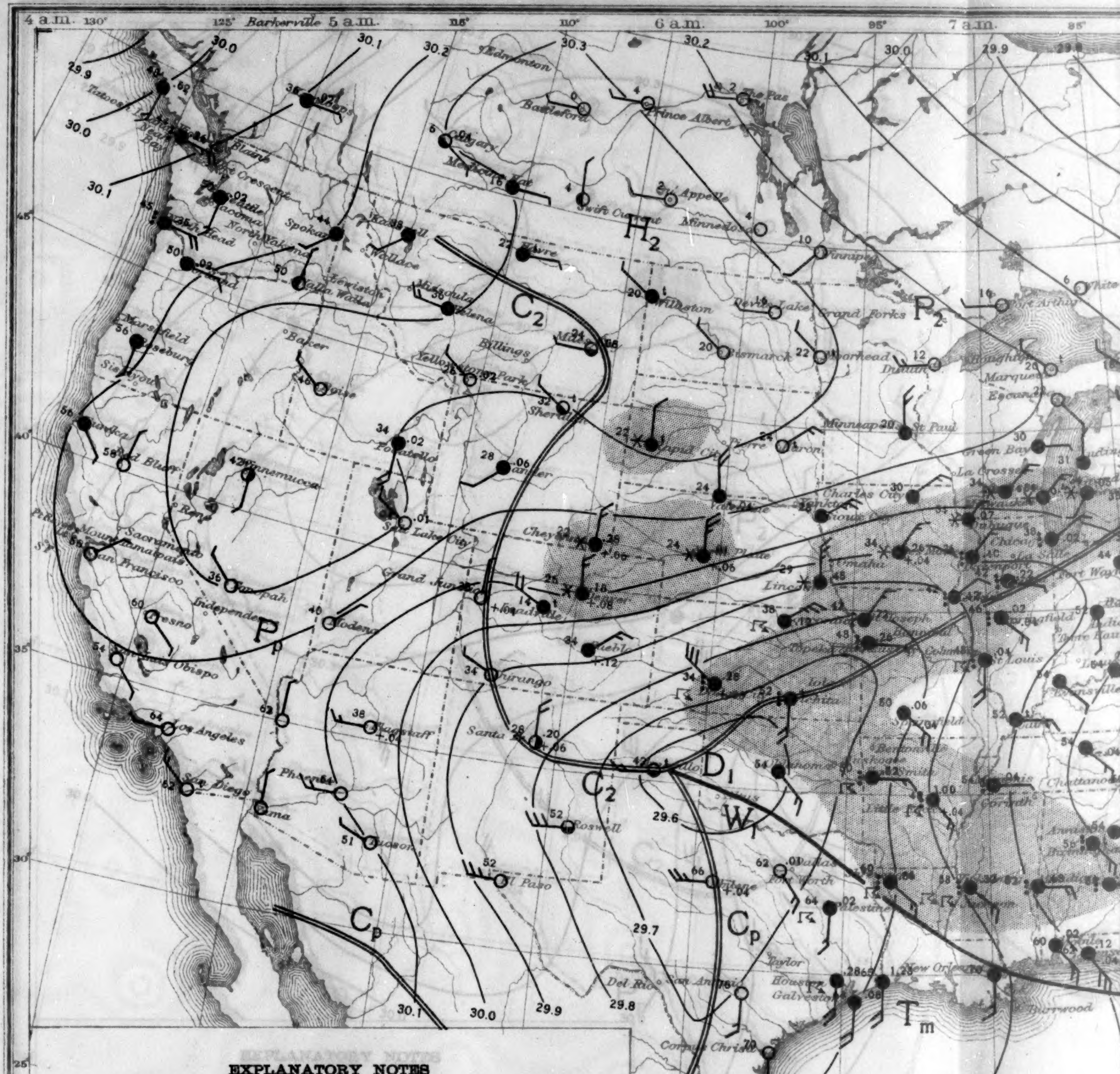


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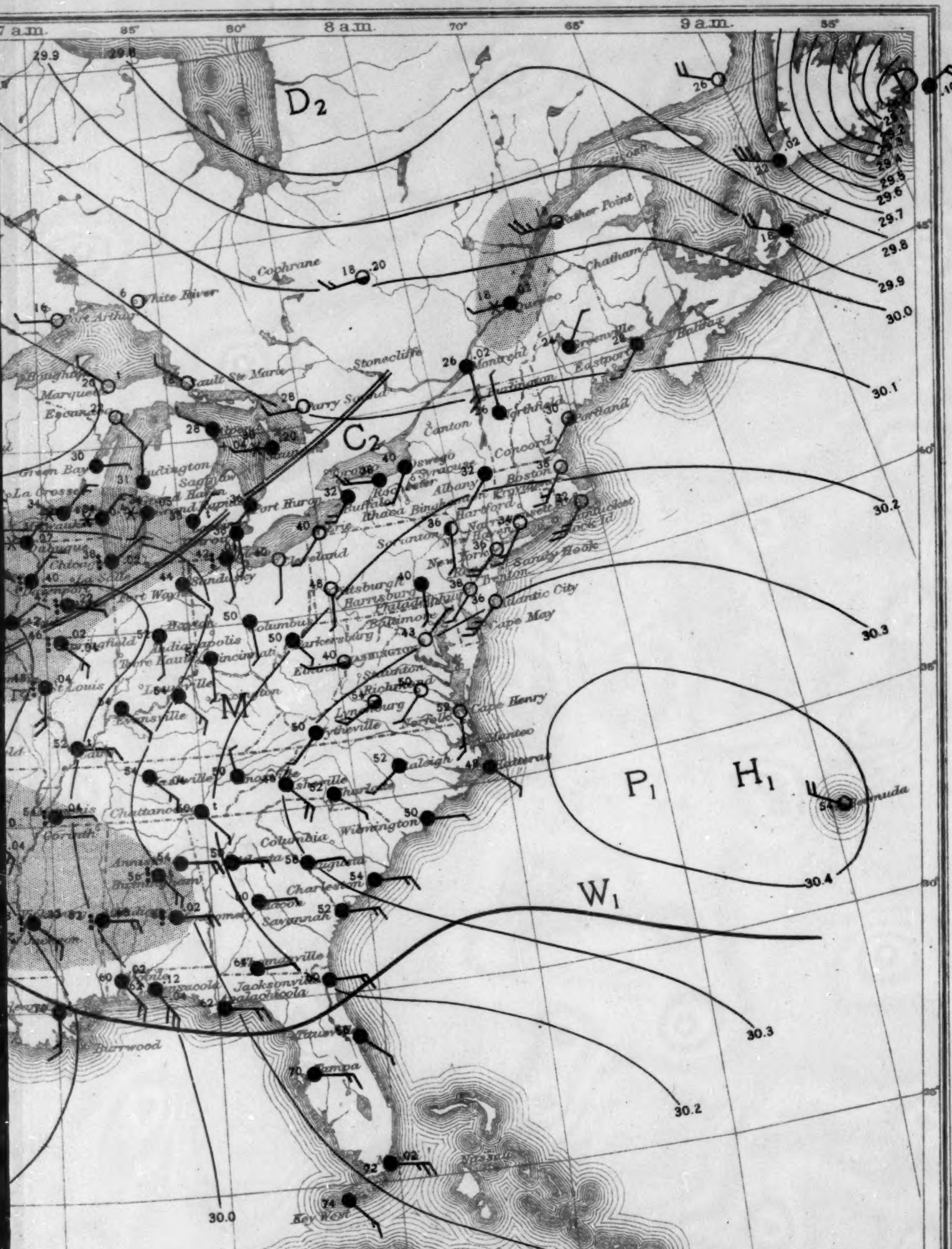
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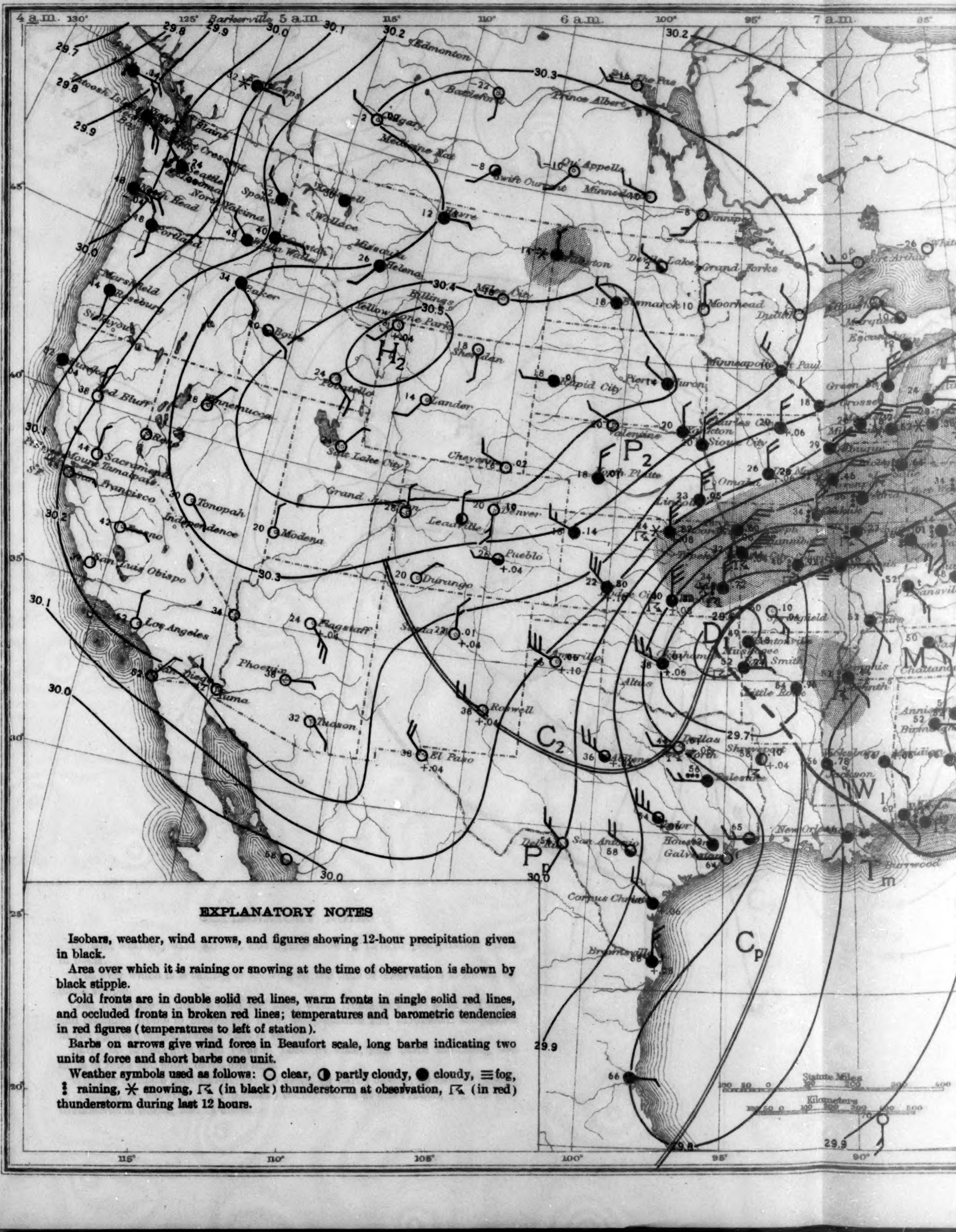


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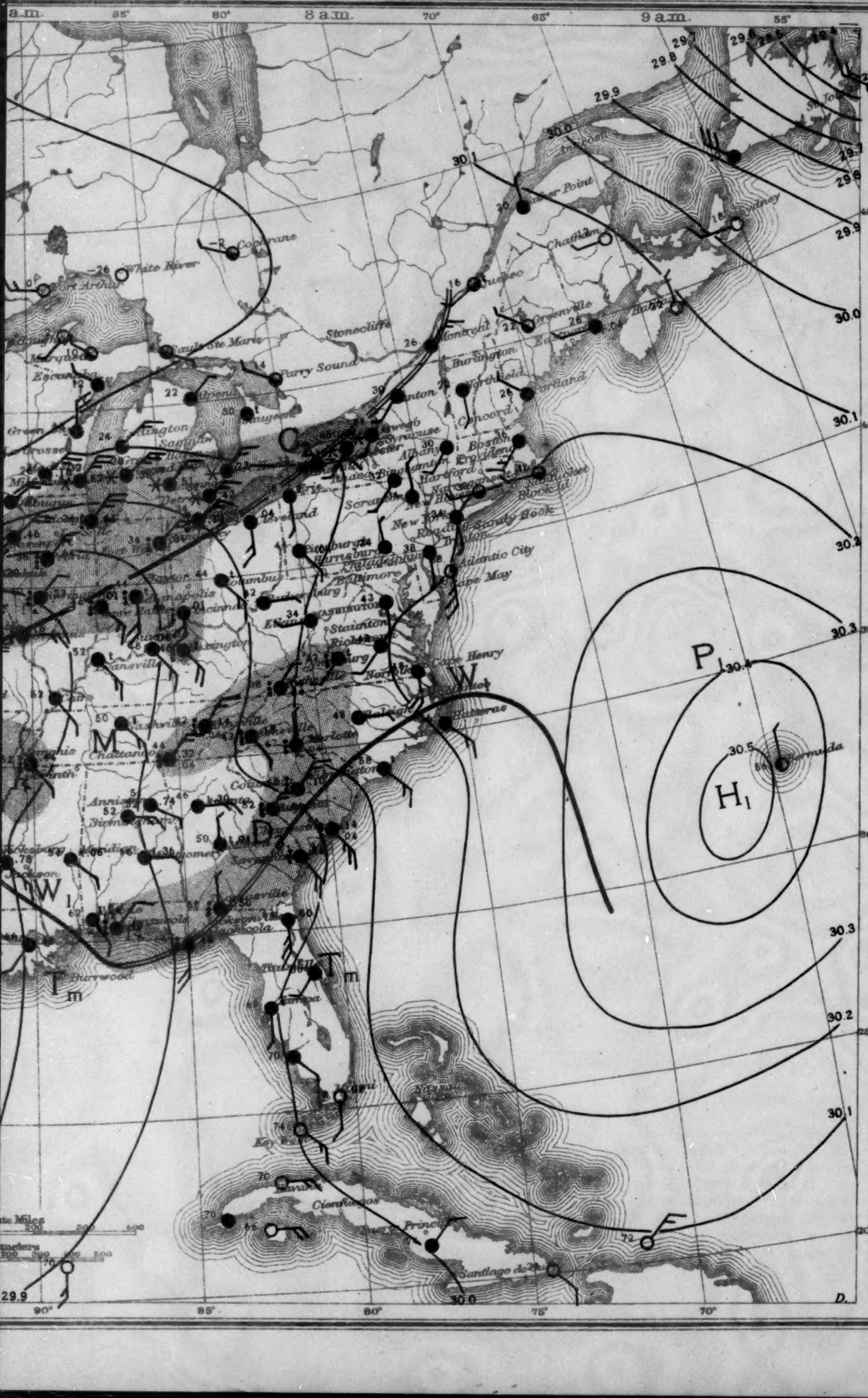
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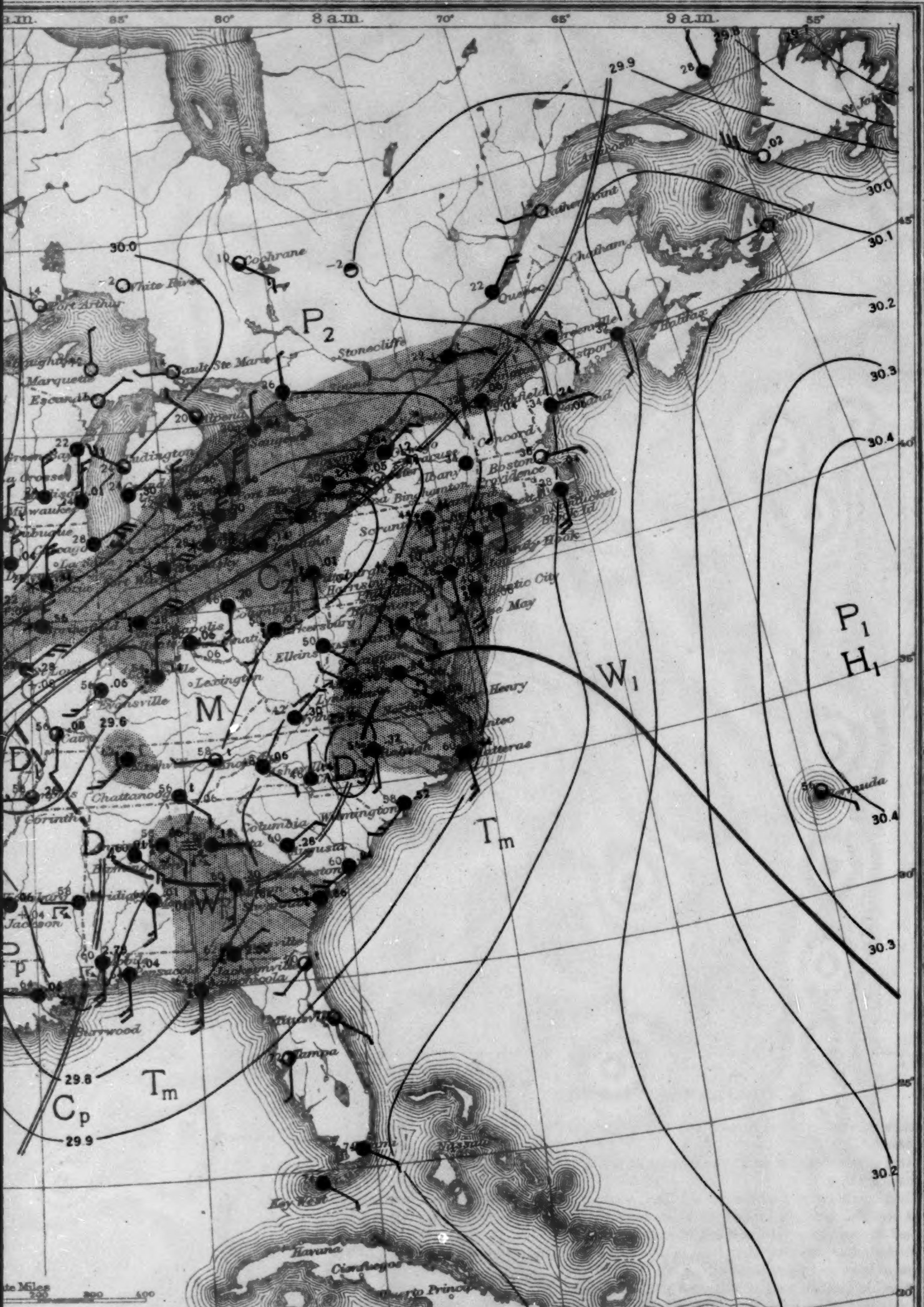
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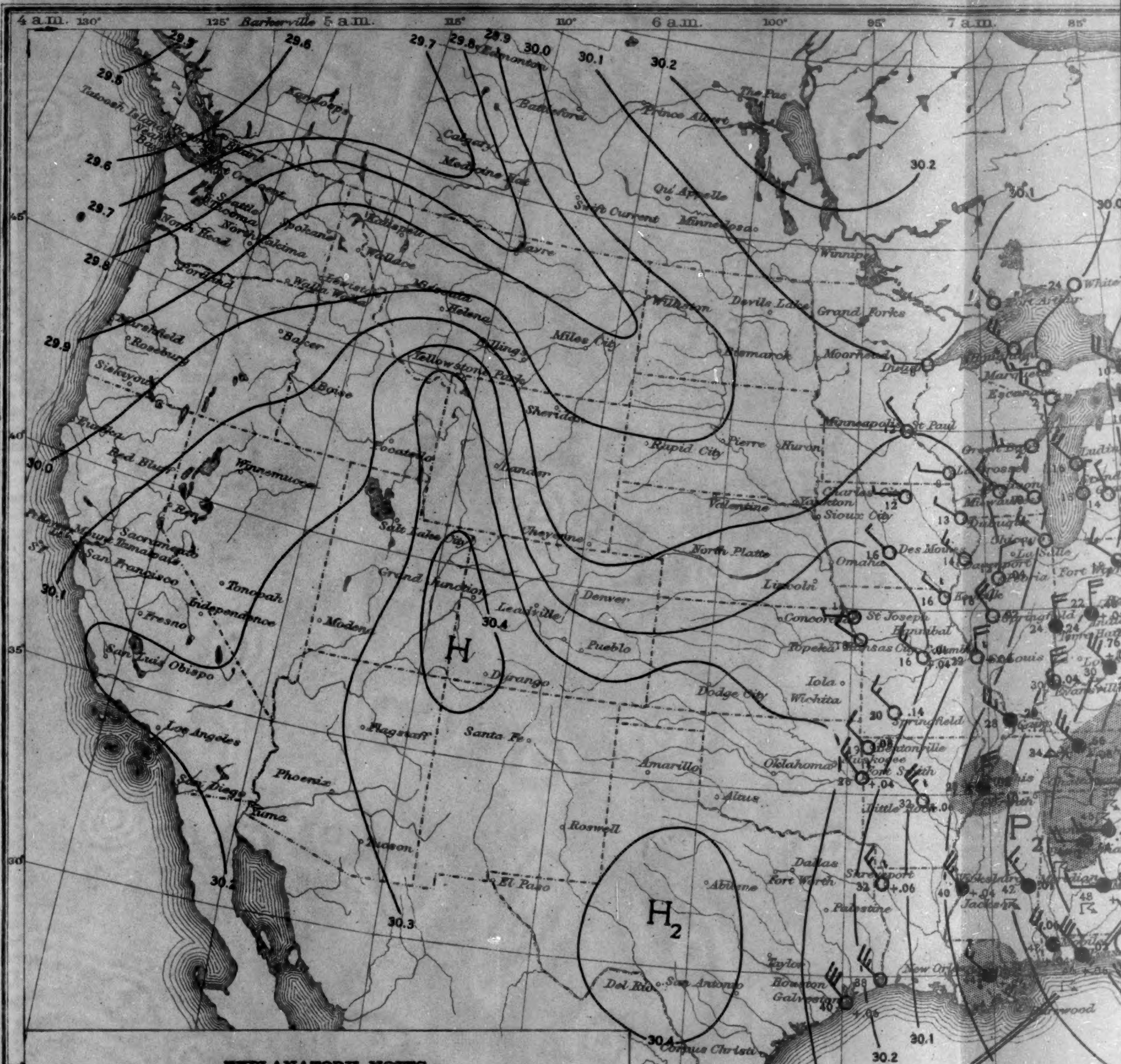


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# "THE GLACIAL ANTICYCLONES:" A REVIEW[1]

By CHARLES F. BROOKS

[Clark University, Worcester, Mass.]

William H. Hobbs: "The Glacial Anticyclones: the Poles of the Atmospheric Circulation." Univ. of Mich. Studies; Sci. Series, vol. IV, xxiv+198 pp., 53 figs., 3 pls., index, bibliog. Macmillan, New York, 1926.

*Essence of Doctor Hobbs' theory of the glacial anticyclone.*—1. Many features of the winds, character of the snow, and temperature changes indicate that several fixed anticyclones exist over the Antarctic and Greenland ice domes.

2. Most significiant is the centrifugal flow of the cold surface air prevailingly down slope, though deflected by the earth's rotation. Light winds and calms prevail on the central flat regions, but the winds increase in velocity toward the margins, where they may attain great violence. The more or less constant outward sweep of the winds, the "centrifugal broom" carries much of the inland snow from the higher slopes toward the margins or into the sea.

3. The upper currents stream at times toward the anticyclonic centers, carrying with them cirriform clouds, which apparently evaporate in the settling air over the ice domes. The moisture from these clouds as well as the uncondensed water vapor are evidently the material for much, if not most, of the snowfall of the interior. The precipitation of this vapor normally occurs near the chilling surface without the intermediate formation of clouds.

4. The temperature of the lower air closely depends on that of the surface. During periods of calm the snow or ice surface cools the atmosphere to a considerable height. Under the influence of gravity this cold air tends to flow down the slopes, giving rise to the blizzards of the margins, with the downward acceleration of the wind the rate of warming by compression increases and ultimately exceeds the rate of cooling by radiation and conduction. This warming automatically stops the blizzard, and another calm period sets in, during which the cold air again accumulates. Such is the apparent mechanism of much of the weather on the margins of Greenland and Antarctica.

5. The central calm and the downward and outward flow prevails apparently throughout the year and is not often interrupted by passing cyclones. Associated with these permanent glacial anticyclones are permanent cyclones, chiefly the Iceland cyclone and those in the Weddell and Ross seas. Thus it is evident that the general circulation of the atmosphere in high latitudes is complete and intimately related to the location of ice domes and neighboring open seas.

It has long been known that over a cold region air contracts and accumulates then spreads outward at the lower levels, and that cold air slides down a slope. Also, decades ago, explorers on the ice cap of Greenland had noted the down-slope winds. But the credit for first visualizing the circulation over ice caps as wholes, collating a large body of data from diverse sources, and erecting a working hypothesis of the glacial anticyclone belongs to Doctor Hobbs. Promulgated first in 1910 and 1911 and presented in detail in 1915, this was taken nto the field by explorers of the continental ice sheets and was found adequate in its essentials. Doctor Hobbs's book now presents these newer data, relating them to the conclusions gleaned from the older.

*The book.*—The opening portion of the book is occupied by an appreciative preface by Dr. H. R. Mill, followed by the author's historical sketch of his theory, and a criticism of early views of atmospheric circulation, including Ferrel's.

The body of the work summarizes the early explorations of Greenland and Antarctica, and what might be called the second period of exploration of continental glaciers, all fully referenced. Here is interjected a detailed discussion of the characteristics of the glacial anticyclone. New material from the latest period is then added and correlated with the earlier conclusions.

The glacial anticyclones are now placed in the general atmospheric circulation. Then glacial anticyclones of the past are outlined. Present opinion is criticized and problems for further research are mentioned in conclusion.

This approximately historical treatment places the facts before us, to be sure, while references to further details are abundant. Indeed, this volume has considerable value simply as a reference book to polar exploration during the past 100 years. But, after reading all the details, one gains the impression that the author was more intent on blaming meteorologists for not generally recognizing glacial anticyclones and their importance in the general circulation than on marshalling the facts for the presentation of his theory point by point. The glacial anticyclone has not enjoyed the reception it might have had if Doctor Hobbs had not failed to make his main points clear by befogging them with controversy, overpositiveness, and meteorological errors.

It seems unfortunate that in presenting his theory Doctor Hobbs thought it necessary to discount Ferrel's. The glacial anticyclone is an addition to the group of continental winds, which winds are not involved in discussions, like Ferrel's, of planetary circulation. Ferrel's polar calms and outflowing surface winds are in accord with present knowledge, while observations during the past forty years have apprised us of the details of continental interruptions to the theoretical planetary circulation of the higher latitudes.

A real enthusiast claims more for his theory than the available facts appear to others to warrant. Under the heading "The destructive cyclones of Europe sent out during the stroph of the anticylcone" (p. 153) Doctor Hobbs appears highly speculative:

> The great volume of air which pours out from the Greenland inland ice during the stroph of the anticyclone, at the surface and in the lee of the ice cap, halts abruptly [?] just at the contact with the migrating cyclones along the coast. At higher levels this in its outward movement must certainly pass upward within the adjacent migrating cyclones [ref. to Lockyer], and it must impart to them a vigor which near the ground will increase as they travel.

We wonder if this can be so, and await the illumination that only observations can provide. "The climatic zones which are characteristic of the present age," Doctor Hobbs says, "would appear to be due largely to the existing glacial anticyclones . . ." (p. 54). We can not admit this to be possible without implying that the continental glaciers in high latitudes could be formed if there were no cold zone, though it is true that, once formed, they should lower the temperature further, thereby accentuating, but not creating, zonation.

When a geologist writes a book on winds and weather, it is not surprising to find a number of meteorological errors in it. Ice crystals of cirrus clouds descending over

[1] Presented, in more extended and slightly different form in a symposium on Greenland, at a joint meeting of the American Meteorological Society, Association of American Geographers, and Section E of the American Association for the Advancement of Science, Philadelphia, Pa., Dec. 30, 1926.

the ice caps of Greenland and Antarctica are not likely to melt before vaporizing, as Doctor Hobbs reiterates (pp. 2, 52, 131). Latent heat can not further augment an elevation of air temperature (p. 131). To apply the term "vortex" to an anticyclone (pp. 34, 100, 127) is a misuse of the word. (Cf. "Meteorological Glossary", Brit. M. O. 225 ii, pp. 347–351, 1918.) Likewise, it is a misappropriation of the term "eye" in meteorology to speak of "Eye of glacial anticyclone" (fig. 18). An intense cyclone is said to have an eye when it has a sharply limited central region more or less calm and clear. The author's idea of a limited central area of descent appears to have been gained from an ingenious experiment in which, however, the coloring matter to show the streamlines of descent over a cold dome was restricted to only a central portion of the fluid, thereby giving a fictitious semblance of limited circulation in a form suggestive of a vortex (Pls. II and III, and fig. 18).

*Four important points still to be settled are*—(1) the relative importance of the general low temperature and of the slope in the strength of the glacial anticyclone, (2) the nature and extent of the upper inflow of air (3) the alimentation of the ice sheet, and (4) the locations of the permanent large high pressure areas in high latitudes.

1. A snow or ice field at sea-level surrounded by open water would be marked by an anticyclone. But how strong would it be? Doctor Hobbs insists, on the other hand, that the slope of the cold glacial dome is responsible for the anticyclone over it. When we have enough surface and aerological observations, perhaps we can determine to some quantitative degree how much of the wind velocity of the "glacial" anticyclone is due solely to the slope over which and down which the outflowing cold air travels.

2. It seems to the reviewer that Doctor Hobbs' idea of a distinct downdraft in the interior free-air portion of the glacial anticyclone is far too strong for what probably occurs over the exceedingly broad and apparently nearly level expanses of the interiors of Greenland and Antarctica. The amount of air involved in the downward and outward flow along the surface of the ice is small relative to the total air in the troposphere over the dome. It is, therefore, unnecessary to demand a well-defined inward flow and descent. Aerological observations in west Greenland do show a turning of winds with altitude till there is a slight average inward component of motion. But there appears to be no direct flow to the interior, as suggested by Doctor Hobbs, nor anything approaching an upper air cyclone, as some others demand for the formation of the precipitation. All balloon evidence seems to point to the Greenland anticyclone being essentially a ridge of high pressure extending nearly to the top of the troposphere. Cyclones greatly disturb this anticyclone, at times even wiping out the entire southern portion.

3. The point in Doctor Hobbs' theory, that has been open to perhaps the greatest criticism is his claim for anticyclonic alimentation of the ice sheet. Nobody denies there is precipitation in the far interior of the glacial anticlone; that is self-evident from the presence of the glacier and the almost continuously outward-moving drift snow. The sticking point with some critics is, how can precipitation occur in compressionally warmed descending air? In the interior of Antarctica temperatures below −75° F. have been observed, and it is not unlikely that equally low temperatures occur in the interior of Greenland, since Nansen experienced temperatures well under 40° F. below zero there even in September. Therefore, it is readily possible for air that has descended even 4 or 5 kilometers onto the ice dome to yield frost or frost fog precipitation even if this air contained no condensed vapor in the form of cirrus clouds before it descended. Explorers have found this type of precipitation to be common in the cold interiors of Greenland and Antarctica.

It seems likely, however, that on the margins of the ice-dome the precipitation from ascending air is far greater than any frost fog, while in the cold interior, much drier in the absolute sense, the precipitation from ascent may fall behind that from chilling at the surface, the total from the two causes together being greatest at the margins and least in the farthest interior.

4. In the south polar region, the center or centers of highest pressure throughout the year are unquestionably over Antarctica. In the north polar region, however, there is some doubt whether the actual north pole of the air circulation of the globe throughout the year is over Greenland as Doctor Hobbs claims. In winter, there is the well known great extension of the polar high pressure conditions into Asia and North America, while in summer high pressure conditions appear to be restricted to the Arctic Ocean and Greenland, with a reasonable possibility that, in addition to the apparent high pressure center over or near northeast Greenland (Cf. MONTHLY WEATHER REVIEW, 51:260), there may be one in the great unexplored areas north of Alaska and the Yukon. It seems that the general Greenland HIGH is north of the latitudinal middle of Greenland where centered by Doctor Hobbs, being a compromise between the tendencies to high pressure both over Greenland and over the polar basin immediately about the North Pole. (Cf. Buchan's charts, plate 13, in Bartholomew's Atlas of Meterology.)

*Conclusion.*—These questions will disappear as the facts become better known, and they do not involve the main points of the glacial anticyclone theory, of a more or less pulsatory prevailing outflow of air down the slopes of an ice-cap, with a necessarily compensatory inflow aloft, and the occurrence of precipitation all over the dome. Some of the miscellaneous errors noted will be corrected, and differences with meteorologists can be smoothed out, though it is not to be expected that all others will see so far reaching an importance nor so many ramifications of the theory as its keen and enthusiastic proponent urges. As a full collation of polar wind observations relative to the glacial anticyclonic circulation, Doctor Hobbs' monograph is an outstanding contribution to polar meterology.

## NOTES ON FORMULAS FOR USE IN FORECASTING MINIMUM TEMPERATURE

By E. S. NICHOLS

[Weather Bureau Office, San Jose, Calif., Sept. 21, 1926]

### USE OF EQUATION OF HYPERBOLA IN FORECASTING FROM HYGROMETRIC DATA

An examination of several dot-charts showing the relation between relative humidity and departure of ensuing minimum temperature from the dew-point leads me to the conclusion that, in many cases at least, the equation of a hyperbola expresses the relation even better than does the parabolic formula often used. It is proposed herein to use the rectangular hyperbola with asymptotes parallel to the axes of coordinates of the dot-chart, having, therefore, the general equation,

$$(X-a)\ (Y-b)=K$$

where the point $(a, b)$ is the intersection of asymptotes and $K$ is a constant depending upon the form of the curve. For use in forecasting minimum temperatures, this equation is to be solved for $Y$, giving us

$$Y=\frac{K}{X-a}+b.$$

The values of the parameters, $a$, $b$, and $K$, for any particular chart can be computed easily by solving three equations obtained by substituting in our general equation three pairs of values of $X$ and $Y$ taken for three selected points along the curve best fitting the plotted data (relative humidity as abscissas, departures of minimum temperature from dew-point as ordinates), drawn free-hand. The method of procedure is now illustrated:

Figure 1 is a chart of this kind prepared from data for San Jose, California, for March during the period, 1914 to 1925, inclusive, considering cases with clear skies at observation time in the morning. The points chosen for computing the constants of the desired equation are (15, 24), (40, −2), and (70, −10), indicated by the letters A, B, and C, respectively, on the chart. Substituting these three pairs of values in the general equation, we have

$$\begin{aligned}
&(A).\ (15-a)\ (\ \ 24-b)=K=\ \ \ 360-24a-15b+ab\\
&(B).\ (40-a)\ (-\ 2-b)=K=-\ \ 80+\ 2a-40b+ab\\
&(C).\ (70-a)\ (-10-b)=K=-700+10a-70b+ab
\end{aligned}$$

Eliminating $K$, by equating its values from (A) and (B), and then those from (B) and (C), we have

$$\begin{aligned}
&(1).\ 26a-25b=440\\
&(2).\ \ 8a-30b=620
\end{aligned}$$

Eliminating $a$ from (1) and (2), we have, $b=-21.7$
Substituting this value in (2), we get, $a=-3.9$
Substituting in (A), we obtain, $K=863.7$
Then our desired equation is, using whole numbers for constants

$$Y=\frac{864}{X+4}-22.$$

We may check this equation by substituting therein a value of either unknown taken from the curve, and comparing the value of the other unknown thus computed with the corresponding value on the curve. Thus, where $X=26$ we get,

$$Y=\frac{864}{26+4}-22=6.8,$$

which agrees with the value from the curve. Again, where $X=46$ we have,

$$Y=\frac{864}{46+4}-22=4.7,$$

which agrees closely with the curve.

A similar equation may be derived for Grand Junction, Colorado, from Figure 7A on page 43 of Supplement No. 16 to the Monthly Weather Review. Take the three points (10, 34), (25, 16), and (55, 0). Then we have

$$\begin{aligned}
&(A)\ (10-a)\ (34-b)=K=340-34a-10b+ab\\
&(B)\ (25-a)\ (16-b)=K=400-16a-25b+ab\\
&(C)\ (55-a)\ (\ 0-b)=K=-55b+ab
\end{aligned}$$

From which we obtain: $a=-20$, $b=-24$, $K=1{,}800$, and the equation,

$$Y=\frac{1{,}800}{X+20}-24.$$

When $X$ is 40, e. g., this gives a value of 6 for $Y$, which agrees closely with the curve. When $X$ is 5, $Y$ is 48, which agrees with plotted data better than the curve drawn.

Taking Fig. 6, for El Paso, Tex., on page 11 of the same supplement: Choose the points (5, 50), (15, 25), and (35, 10), and we obtain: $a=-7.9$, $b=-7.2$, $K=737.9$, and our equation is, using whole numbers,

$$Y=\frac{738}{X+8}-7.$$

From this equation we compute the following pairs of values: $X$, 22, $Y$, 17.6; $X$, 10, $Y$, 34; $X$, 2, $Y$, 66.8. These values seem to fit the plotted data even better than the line drawn.

Again, taking Fig. 2 on page 528 of the Monthly Weather Review for October, 1922, minimum temperature prediction graph for Spokane, Wash.; choose the points (10, 30), (30, 10), (60, 0), and we have equations giving for $a$ value, −15, for $b$, the same, and for $K$, 1125. The hyperbolic equation for this curve is, therefore,

$$Y=\frac{1{,}125}{X+15}-15,$$

which agrees closely with the data entered on the chart.

### ARRANGEMENT FOR CONVENIENT COMPUTATION

Our general equation may be adapted to logarithmic computation. Thus, by transposition, we have

$$Y-b=\frac{K}{X-a}.$$

Then, $\log\ (Y-b)=\operatorname{Log}\ K-\log\ (X-a)$.
The following form of table may be used for convenience:

| | | | | | |
|---|---|---|---|---|---|
| $X$ (Rel. Hum.) | | | | | |
| $a$ | | | | | |
| $X-a$ | | | | | |
| $\log\ (X-a)$ | | | | | |
| $\log\ K$ | | | | | |
| $\log\ (Y-b)$ | | | | | |
| $(Y-b)$ | | | | | |
| $b$ | | | | | |
| $Y$ | | | | | |

### USE OF DOT-CHART IN FORECASTING

It is well, in actual practice, to have at hand the original dot-chart on which the graph of the derived equation has been plotted, in order that, from "variations in scattering of dots in different regions," one may note "roughly what dependence may be placed on different portions of the curve." In fact, some may prefer to avoid the labor of computing the constants of an equation and to depend upon a curve drawn free-hand, as previously suggested in Supplement No. 16, already referred to; in this case it is unimportant whether the curve be of parabolic, hyperbolic, or other form, since

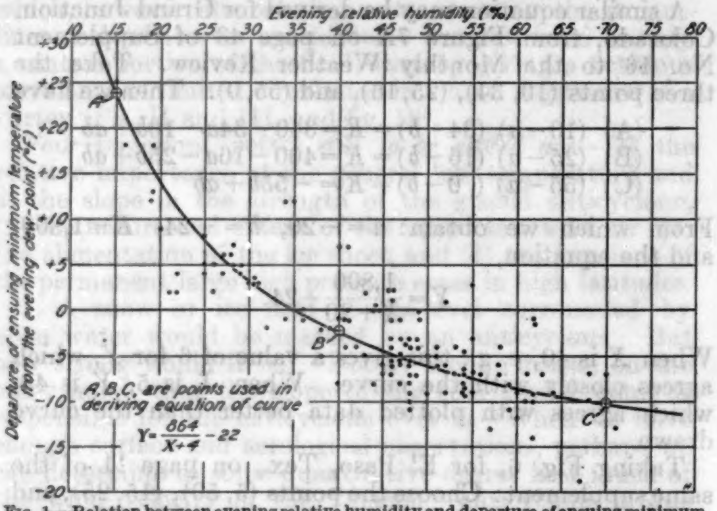



FIG. 1.—Relation between evening relative humidity and departure of ensuing minimum temperature from the evening dew point at San Jose, Calif. (Based on data for March, 1914 to 1925, inclusive, during clear weather)

results will be taken directly from the graph, without computation.

### COMPARISON OF PARABOLA AND HYPERBOLA USED

In some cases, the parabola and the hyperbola appear to fit the plotted hygrometric data equally well. Sometimes, however, the parabola whose constants have been derived fits well the main body of data but departs at either or both high and low values of relative humidity. These departures are due, directly and indirectly, largely to the recurvature that takes place at the vertex of the parabola. Thus, in the case of El Paso, considered above, the upper portion of the given parabola lies below the most of the dots (at low relative humidities), while recurvature upwards takes place among the dots for the higher humidities (but still at comparatively low humidity values). But, if we change the form of the parabola to conform to data in the upper portion, recurvature becomes sharper.

In any case, taking the equation of the parabola in proper position to fit the data plotted as considered in these notes, we have, $Y=a+bX+cX^2$, where $a$, $b$, and $c$ are constants. Then the vertex of our parabola lies at the point where $X$ has the value $-\frac{1}{2}b/c$, and recurvature upward takes place at this point (i. e., $Y$ increases thereafter at an increasing rate, with increase of $X$), as may be shown by the methods of Calculus. Thus, differentiating, we get

$$\frac{dy}{dx}=b+2cx$$

slope of the curve. This, at the vertex is 0; then we have,

$$b+2cx=0;\ x=\frac{1}{2}\frac{b}{c}.$$

If this point be at or beyond the highest relative humidity value ($X$) used in forecasting, no harm is done.

This (sometimes) objectionable recurvature does not take place in our hyperbola; this curve continues downward (with decreasing angle with the $X$-axis), at high values of $X$ becoming approximately horizontal.

The method employed above in deriving constants for hyperbolic equations is an adaptation of the "Star Point" method of Marvin and Smith which avoids (without sacrifice of useful accuracy, in this problem), "the tedious and laborious least square method."[1]

### PREDICTING MINIMUM TEMPERATURES FROM THE DEPRESSION OF THE DEW POINT BELOW THE MAXIMUM TEMPERATURE

In some cases, by considering the depression of the minimum temperature below the maximum temperature of the preceding day as a function of the excess of that maximum temperature over the dew point observed the same evening, we may obtain a chart or formula that will be useful in forecasting minimum temperatures. In the case of data obtained during the spring of 1926 at the fruit-district substation at Hollister, San Benito County, Calif., the results of this method have been

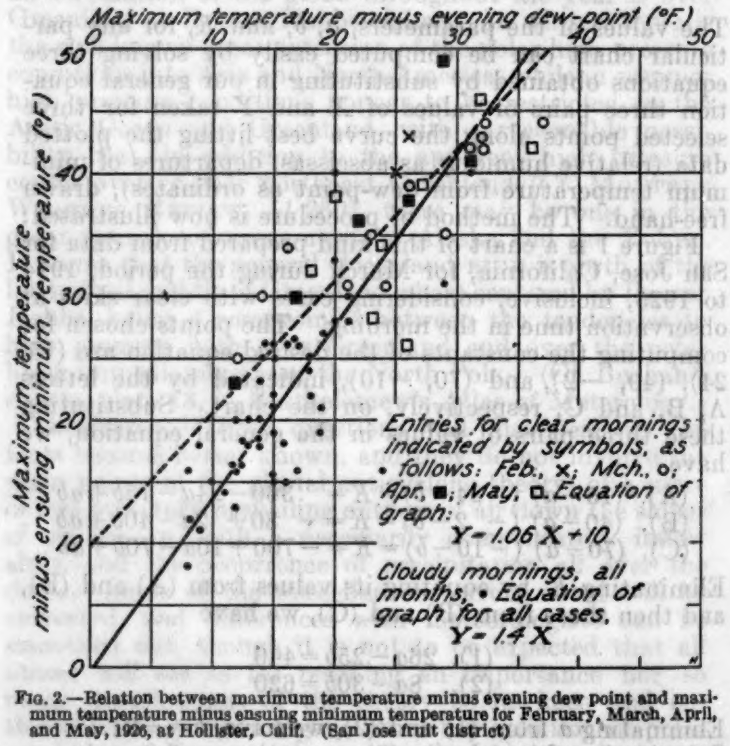



FIG. 2.—Relation between maximum temperature minus evening dew point and maximum temperature minus ensuing minimum temperature for February, March, April, and May, 1926, at Hollister, Calif. (San Jose fruit district)

more promising than those obtained otherwise. Figure No. 2 herewith is a dot chart on which have been plotted, from the Hollister data, depressions of dew points below the maximum temperatures as abscissas and depressions of minimum temperatures below the maxima as ordinates. Cases with clear mornings are indicated by special symbols, and the straight line that appears to fit these cases best has been drawn free-hand; the equation of the line is $Y=1.06X+10$, where $Y$ and $X$ are the specified depressions of minimum temperature and dew

[1] Supplement No. 16, MONTHLY WEATHER REVIEW.

point, respectively. For all cases the straight line $Y=1.4X$, has been drawn. Forecasting by this method, considering the scattering of dots from the graphs, would be equally successful in clear or cloudy weather.

It will be noted that this method is essentially a modification of my maximum-minimum temperature method (described in Monthly Weather Review Supplement No. 16 and elsewhere) by considering the effect of moisture in retarding cooling.

## THE TORNADO

By W. J. HUMPHREYS

[U. S. Weather Bureau, Washington, January, 1927]

The tornado discussed in what follows is the typical "twister" of the American prairies, and may be defined as a slightly funnel-shaped, or flaring, hollow, circular column of upward-spiraling winds of destructive velocity. It is the most violent, least extensive, and most sharply defined of all storms. Its appearance and effects often have been described. There is no satisfactory account, however, of its origin. Hence it seems worth while to assemble the more common facts of observation in connection with this type of storm, and to deduce therefrom whatever we can in regard to its genesis. These deductions, being something definite to prove or disprove, will at least help to fix one's attention and thereby hasten, it is hoped, the ultimate solution of this difficult meteorological problem.

Some of the normal, but not all of them invariable, circumstances of place and meteorological conditions connected with the occurrence of tornadoes are the following, the more important, from the standpoint of this paper, being numbered with boldface type.

**1.** *Geographic location.*—Central and southeastern United States, chiefly; next, perhaps, southern Australia, though Griffith Taylor says, in his *Australian Meteorology*, "tornadoes are not common in Australia"; and several other parts of the world occasionally, except in general the tropical regions. The so-called tornado of tropical west Africa appears to be a violent thunderstorm of the squall type. The tropical waterspout is relatively mild, and of a more or less different origin.

**2.** *Meteorological location.*—Southeastern section, or, more exactly, east of the wind-shift line, of a LOW, or cyclone, of moderate to decided intensity.

3. *Kind of cyclone.*—The trough or V-shaped, the kind productive of secondary cyclones, is very favorable, especially when the V protrusion points southward, or, more particularly, southwestward. However, tornadoes occur also when this protrusion of the isobars is not conspicuous, if indeed present at all, at the surface of the earth.

**4.** *Other pressure distribution.*—A moderate anticyclone to the rear, that is, west or northwest, of the cyclone, appears to be an invariable condition; but even if this pressure distribution be essential, as we believe it is, to the genesis of the tornado there is no proof of it from statistical evidence alone, since normally the extratropical cyclone has an anticyclone to its rear.

5. *Surface pressure gradient in region of tornado.*—Usually moderate to steep in comparison with the average cyclone.

**6.** *Horizontal temperature gradient.*—Usually steep along a portion of the border between cyclone and anticyclone.

**7.** *Previous wind.*—Moderate to fresh southerly, often southwest.

8. *Following wind.*—Moderate to fresh, northerly, often northwest.

9. *Previous temperature.*—At 8 a. m. 70° or over and increasing.

10. *Following temperature.*—Distinctly lower than just before the storm.

11. *Previous humidity.*—Excessive—making the air, at its high temperature, sultry and oppressive, from hours to even days before.

**12.** *Clouds.*—Heavy cumulo-nimbus, from which a funnel-shaped cloud depends. Sometimes this cumulus is isolated and very towering, but, when not isolated, often preceded briefly to an hour or longer by mammato-cumuli.

**13.** *Precipitation.*—Rain and usually hail 10 to 30 minutes before; light precipitation at instant of storm (funnel cloud often clearly seen and occasionally photographed); deluge of rain, mixed at times with small hail, shortly after.

**14.** *Lightning.*—Nearly, or quite, invariably lightning accompanies the tornado, but seldom, if at all, occurs in the funnel cloud.

15. *Sounds.*—There always is a loud rumbling or roaring noise while the whirling pendant cloud is in touch with or even closely approaches, the earth.

**16.** *Direction of tornado wind.*—Spirally upward around a traveling axis, and in the same sense as the accompanying cyclone—counterclockwise in the northern hemisphere.

17. *Horizontal velocity of wind in tornado.*—Unmeasured, but destructively great.

18. *Vertical velocity of wind in tornado.*—Also unmeasured, but sufficient to carry up pieces of lumber and other objects of considerable weight—say 100 to 200 miles per hour.

**19.** *Location of initial and sustaining whirl.*—Above, probably close above, the general cloud base.

20. *Velocity of storm travel.*—Usually 25 to 40 miles per hour.

21. *Length of path.*—Anything up to possibly 300 miles, usually 20 to 40 miles.

22. *Direction of travel.*—Roughly parallel to travel of the center of the general or cyclonic storm, hence usually northeastward.

23. *Width of storm.*—Anything from 40 to 50 feet up to, rarely, a mile or even more, but averaging around 1000 feet. Many are only 500 to 600 feet across and others, as stated, even much less.

24. *Number.*—Usually several, often in groups, in connection with the same low-pressure system, and on the same day.

25. *Time of year.*—Mainly spring, and early to midsummer, but occasionally also at other seasons.

26. *Time of day.*—Usually midafternoon, or 3:00 to 5:00 p. m.

All the foregoing meteorological conditions are inferred from observations at the surface of the earth, and not in the free air one or two kilometers above the surface, where the tornado seems to have its origin. Data from this obviously desirable upper level appear to be very scanty. However, through the kind assistance of the Climatological and the Aerological divisions of the United States Weather Bureau, 26 cases were found where observations by sounding balloon or kite, or both, were made less, to much less, than six hours from the time of and nearer—some far closer—than 100 miles from, a tornado. These observations indicate (they are too few to prove anything) that when tornadoes occur the wind, whatever its value at the surface, is strong (around 20 to 25 meters

per second or, say, 50 miles per hour) at the height of one to two kilometers. In some cases the direction of the wind is nearly constant throughout at least the lower two kilometers, the approximate depth explored. Sometimes it backs, turns counterclockwise, perhaps 30°, but usually veers at this height, roughly 45°.

Mid-air temperature inversions appear to be quite common and the lapse rates next above these inversions very rapid, often nearly or quite of adiabatic value. In short, so far as one can infer from these few observations, the atmosphere in the neighborhood of a tornado appears to be unusually stratified, and tending to become unstable at one or more levels. But we must remember that even these observations, the best we have, were taken at distances too great to give reliable information about so very local a disturbance as the tornado. They may be suggestive in this connection, but they are not conclusive.

As implied, several of the above circumstances and meteorological conditions are only usually, and not invariably, associated with the tornado, nor perhaps are they all that have any importance in respect to its genesis and maintenance. Nevertheless, they are among the more conspicuous and sufficient, it would seem, to restrict explanations to those that contain elements, at least, of the truth.

*a.* Since the linear velocity in whirls frictionally created between passing currents, whether liquid or gaseous, cannot exceed that of these currents relative to each other, it follows that the tornado, whose winds far surpass this limiting value, is generated in some way that is not purely mechanical.

*b.* The only other way by which vortical motion is produced naturally in the atmosphere is that of drawing closer together, through vertical convection, masses of air the algebraic sum of whose angular momenta about the center of that convection is greater than zero, whether positive, rotation in one sense, or negative, with opposite rotation. Here the Principle of Conservation of Angular Momentum, or conservation of areas, is operative, by virtue of which the linear velocity, except as reduced by friction, so increases as the distance from the center decreases that the product of this distance and the velocity is a constant.

In this way, and in no other, persistent whirls in the air of great linear velocity can and do occur naturally where the interference, frictional and turbulent, is quite small. That is, in the free air, from where they may, and often do, feed down to the surface.

*c.* The production of a violent whirl in the air, through the conservation of angular momentum, requires (1) a central or localized vertical convection at the level at which the whirl begins; and (2) that the currents drawn into the ascending column have initially either different directions, or different speeds if originally in the same direction. Local convection does not produce rotation in still air, nor in wind that has the same direction and speed throughout except, in each case, to the slight extent caused by the rotation of the earth. The ordinary dust whirl is induced by convection over a surface across which the flow of air is so disturbed as to miss the center of convection and start a spin. This spin may be in either sense, clockwise or the contrary, from which it follows, as also from other considerations, that the dust whirl and the tornado, which always turns in the same sense, are radically different in origin.

*d.* Kite, pilot-balloon, and cloud observations all show that the winds one or two kilometers above the surface are moderately swift in the neighborhood of a tornado, and increased over the surface winds more than commonly is the case at that level. These observations also indicate that the rapid velocity increase frequently, at least, begins at some intermediate level where a greater or less change in direction also usually occurs.

We infer, therefore, that there are adjacent, presumably superjacent, currents of air of different sources where and whenever tornadoes are likely to occur.

*e.* From the rather common occurrence of the mammato-cumulus cloud shortly before the development of a tornado, it would seem that at the level at which this storm originates there is a superjacent wind cold enough to be unstable with reference to the air just below it. From this fact, and from the approximate to full adiabatic lapse rates that have been found at such times at the cloud level, we infer that on these occasions vigorous convection might be expected—started by gravity instability and intensified by vapor condensation. Furthermore, from the lightning that accompanies the tornado we are sure that there then is strong convection within the clouds, and from the hail that so frequently falls well to the front of a tornado it is evident that the convection is up to great heights and into strong winds.

Now, the southerly winds over the lower and mid-Mississippi Valley, especially, often have rather small lapse rates, very much less than the adiabatic, and therefore are comparatively stable, or difficult to upset convectionally. Over such lower air an upper wind might blow, sinking down only to that level at which its adiabatic warming brings it to the temperatures of the under air at that same height. Presumably, then, in this region the mid-level winds of the southeastern portion of an anticyclone to the west or northwest may flow out over a lower stratum of southerly winds belonging to the adjacent cyclone. In this case there would be a cold front, or squall line, in mid-air, a kilometer, perhaps, above the surface, with a shift of wind direction similar to that which under otherwise like circumstances occurs at the ground when the anticyclonic air extends to the surface, as it usually does.

When the cold front is along the ground the slope of the under surface of the anticyclonic wedge, in the direction normal to this front, is very gentle—a rise of one or two kilometers, say, in a hundred. This condition is due largely to the fact that the velocity of the air near the surface is much less than that at a considerable height, owing, of course, to turbulence and surface drag. Along the mid-air cold front, however, the slope between the two wind systems, the cyclonic and the anticyclonic, presumably is much steeper, as there is no excessive drag at a strata interface.

If now, as seems certainly possible, a cold front should occur some distance above the surface of the earth, it is probable that local convections would develop here and there along it, much as, under similar circumstances, they do along the squall line. Owing, however, to the steeper ascent of the interface between the two wind systems there would be this difference: Convection from the ground, the usual case, would be of overrun or entrapped masses of the warmer and humid cyclonic air up *through* the anticyclonic air above, and would not produce much vorticity no matter how different the directions of the two systems of winds. On the other hand, local convection on a mid-air cold front could be *between* the two wind systems (their interface being steep, as explained) and consist of roughly equal parts from each.

This convection would produce rotation at cloud level, at least in those cases in which the cyclonic winds had a strong southerly component and the anticyclonic, at the

same height, a considerable northerly component. Such winds, if both are being carried bodily with the same velocity, as may be the case, eastward, or, for that matter, along any other course (the principle is general), might differ in direction over the surface of the earth, that is, as seen from the surface of the earth, by almost any angle from 0° to 180°, as determined by the values of their north-south and east-west components, and yet, *with reference to each other, have exactly opposite directions*—be flowing beside and past each other at the same level. In this case they would tend to develop swirls along their more or less vertical interface, of the nature of miniature secondary cyclones, after the fashion of the greater cyclones along any polar "front." In either case, that is, whether convection were of the squall-line type, or started by a swirl like a miniature cyclone, if the air of the major or great cyclone were very humid, and it always is where tornadoes develop, the heat liberated by the incident condensation would increase the convection and consequent spin. This spin, in turn, would drag in the air from lower and lower levels until under favorable circumstances, particularly the existence of a rather rapid lapse rate in the lower air, the surface of the earth was reached. Furthermore, since the rotation of the earth requires the southerly wind to lie east of the northerly, this spin has always to be counterclockwise in the Northern Hemisphere and clockwise in the southern.

Where the two streams, cyclonic and anticyclonic, are drawn together, presumably at or about the cloud level, the velocity of the whirling wind tends to follow the law of the conservation of areas, or to be inversely proportional to the radius of curvature. At lower levels, however, where the spin is the result of a drag from above, the decrease of velocity with increase of radius appears to be much more rapid. Indeed the path of destruction shows so little shading off that generally it is described as being sharply defined, a condition that proves the wind velocity to drop off exceedingly rapidly with increase of distance beyond this boundary.

A familiar detail of the tornado is its pendent, funnel-shaped cloud, caused, as is well known, by the dynamical or expansional cooling of the air under the decreased pressure within the vortex. This decrease of pressure causes houses, in a measure, to burst open as the tornado passes over them. However, it is not very great, probably of the order of one-tenth of an atmosphere, as is readily computed from the spin of the vortex and the rapid decrease of velocity beyond the path of destruction.

The spinning air constitutes a dynamical wall that keeps the outer atmosphere from getting into the region of lower pressure.

The above, or something more or less like it, appears to be the physical explanation of the origin of the tornado. But if so, why then, one asks, are tornadoes so much more frequent in the central Mississippi Valley than elsewhere, and why most frequent there in the spring of the year? Because there, and especially at that season, certain of the conditions listed above are best developed and most frequent; such as very humid southerly winds (having come from over the Gulf of Mexico); a strongly encroaching anticyclone to the west or northwest, and the formation of a mid-air cold front. Why also, one further asks, does the tornado rarely occur in tropical countries? Because, as explained above, it is a joint product of cyclone and anticyclone, one of which, the anticyclone, is there practically unknown.

A complete discussion of the tornado obviously would involve the liberal use of vortex equations. But the data necessary to such a discussion are not avaliable, nor is the theory of the vortex in viscous fluids sufficiently devoloped to be readily applicable to this case.

## THUNDERSTORMS AT LANDER, WYOMING

By McLin S. Collom

[U. S. Weather Bureau Office, Lander, Wyoming]

The mountainous topography of the Lander district is exceptionally favorable for the occurrence of convectional thunderstorms, and of the recorded storms fully 80 per cent appear to have been of this class.

During the 20-year period 1906–1925, inclusive, a total of 408 thunderstorms occurred at or close to the Lander station. A graphical representation of their diurnal distribution indicates that 75 per cent occurred from 11 a. m. to 7 p. m., 14 per cent from 7 p. m. to midnight, and 11 per cent from midnight to 11 a. m., and that the hour of greatest frequency was from 2–3 p. m., with 51 storms, or 12 per cent of the total number. July was the month of greatest frequency, with 26 per cent of the total, and June a close second, with 25 per cent; for December, January, and February not a thunderstorm was recorded.

The storms, as a rule, develop over the mountainous region a few miles from the station. They are frequently intense, but in most instances the greater portion of their energy is expended in the mountains; intense thunderstorms over the adjacent valley are exceptional. Of the storms of record 81 per cent were classed as light, 14 per cent as moderate, and but 5 per cent as heavy.

The prevailing movement was from the southwest, 43 per cent moving from this direction; 19 per cent moved from the west and 18 per cent from the northwest; or, in all, 80 per cent from a westerly (mountain) direction.

Strong winds accompanying the thunderstorms were exceptional. A maximum velocity of from 30 to 40 miles an hour occurred in 14 instances during the 20-year period; but 5 storms were attended by a wind velocity in excess of 40 miles an hour.

Hail attended but 11 of the 408 storms. In all instances the fall was light and except in a few instances caused no damage to tender vegetation.

The thunderstorms of the Lander region are important as factors in both the starting and stopping of fires on the Washakie National Forest. Here the season of greatest hazard (the season which, on account of relatively high temperature and low humidity, most favors extreme dryness of timber and duff) extends normally from about mid-June to September. It is during this season that thunderstorms are most probable. Approximately 10 per cent of all fires that have occurred on the Washakie Forest have been caused by lightning; but the spread of the fires has been limited by the amount and duration of the precipitation attending the storms. During the 20-year period under consideration 55 storms, or 13 per cent of the 408, were recorded as "dry"; 275, or 67 per cent, gave a trace to 0.10 inch precipitation; 48, or 12 per cent, 0.11–0.25 inch; 19, or 5 per cent, 0.26–0.50 inch; and 11 storms, or 3 per cent, gave precipitation in excess of 0.50 inch.

The average height (base) at which thunderstorms pass over the Lander station, computed from the two constants—adiabatic rate of cooling and rate of lowering of the dew point due to expansion—for a limited series of observations was found to be 2,896 feet.

The average rate of movement of the storms selected for special observation, computed by ratio, was 24.6 m.p.h.

Owing to the limited number of thunderstorms which could be observed for determining the foregoing values,

these values are questionable; however, since only storms that were considered to be representative were chosen for special observation, it is believed that the values are reasonably approximate.

Following are detailed tables of all thunderstorms that have been recorded at the Lander station for the 20-year period 1906–1925, inclusive.

TABLE 1.—*Diurnal and annual distribution of thunderstorms Lander, Wyo.*

| | A. M. | | | | | | | | | | | | P. M. | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| January | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | None. |
| February | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | None. |
| March | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | -- | -- | -- | -- | -- | -- | 1 |
| April | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2 | 2 | 2 | 1 | 3 | 1 | 1 | -- | 1 | -- | -- | 1 | -- | 14 |
| May | -- | -- | -- | -- | 2 | 1 | 1 | -- | 1 | 1 | -- | 1 | 8 | 5 | 10 | 3 | 4 | 3 | 5 | 1 | 2 | -- | -- | 1 | 49 |
| June | 1 | -- | 1 | -- | -- | 3 | -- | -- | -- | 2 | 3 | 4 | 14 | 15 | 10 | 10 | 14 | 4 | 8 | 5 | 3 | 3 | 1 | 1 | 102 |
| July | 1 | -- | 1 | -- | -- | -- | -- | -- | 1 | 3 | 3 | 10 | 10 | 7 | 13 | 7 | 8 | 9 | 13 | 5 | 6 | 3 | 4 | 1 | 105 |
| August | 1 | -- | 2 | 2 | 1 | 2 | 2 | -- | -- | 1 | 3 | 11 | 6 | 6 | 10 | 13 | 8 | 6 | 5 | 3 | 2 | 1 | 2 | 4 | 91 |
| September | -- | 1 | -- | -- | -- | 1 | -- | 1 | 1 | -- | 2 | 3 | 4 | 4 | 7 | 6 | 5 | 1 | 1 | 4 | 1 | -- | -- | -- | 42 |
| October | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | -- | 2 | -- | -- | 3 |
| November | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 |
| December | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | None. |
| Total | 3 | 1 | 4 | 2 | 3 | 7 | 3 | 1 | 3 | 7 | 11 | 32 | 44 | 39 | 51 | 42 | 40 | 25 | 32 | 20 | 14 | 9 | 8 | 7 | 408 |

TABLE 2.—*Number of thunderstorms in three classes according to severity*

| | January | February | March | April | May | June | July | August | September | October | November | December | Total | Per cent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Light | 0 | 0 | 1 | 12 | 38 | 77 | 84 | 76 | 39 | 1 | 1 | 0 | 329 | 81 |
| Moderate | 0 | 0 | 0 | 2 | 7 | 19 | 18 | 10 | 3 | 0 | 0 | 0 | 59 | 14 |
| Heavy | 0 | 0 | 0 | 0 | 4 | 6 | 3 | 5 | 0 | 2 | 0 | 0 | 20 | 5 |
| Total | 0 | 0 | 1 | 14 | 49 | 102 | 105 | 91 | 42 | 3 | 1 | 0 | 408 | 100 |

TABLE 3.—*Number of thunderstorms from different directions*

| | January | February | March | April | May | June | July | August | September | October | November | December | Total | Per cent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North | 0 | 0 | 0 | 1 | 0 | 5 | 7 | 4 | 2 | 0 | 0 | 0 | 19 | 5 |
| Northeast | 0 | 0 | 0 | 0 | 2 | 4 | 4 | 3 | 3 | 0 | 1 | 0 | 17 | 4 |
| East | 0 | 0 | 0 | 2 | 3 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 12 | 3 |
| Southeast | 0 | 0 | 0 | 3 | 1 | 2 | 2 | 0 | 3 | 1 | 0 | 0 | 12 | 3 |
| South | 0 | 0 | 0 | 0 | 5 | 2 | 7 | 3 | 2 | 0 | 0 | 0 | 19 | 5 |
| Southwest | 0 | 0 | 0 | 6 | 24 | 52 | 40 | 36 | 17 | 2 | 0 | 0 | 177 | 43 |
| West | 0 | 0 | 0 | 1 | 5 | 20 | 25 | 23 | 4 | 0 | 0 | 0 | 78 | 19 |
| Northwest | 0 | 0 | 1 | 1 | 9 | 15 | 17 | 20 | 11 | 0 | 0 | 0 | 74 | 18 |
| Total | 0 | 0 | 1 | 14 | 49 | 102 | 105 | 91 | 42 | 3 | 1 | 0 | 408 | 100 |

TABLE 4.—*Number of thunderstorms, "dry,"* [1] *and with precipitation*

| | January | February | March | April | May | June | July | August | September | October | November | December | Total | Per cent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| "Dry" | 0 | 0 | 0 | 2 | 1 | 11 | 24 | 8 | 9 | 0 | 0 | 0 | 55 | 13 |
| T.-0.10 inch | 0 | 0 | 1 | 10 | 36 | 70 | 61 | 65 | 30 | 1 | 1 | 0 | 275 | 67 |
| 0.11-0.25 inch | 0 | 0 | 0 | 2 | 7 | 12 | 11 | 14 | 1 | 1 | 0 | 0 | 48 | 12 |
| 0.26-0.50 inch | 0 | 0 | 0 | 0 | 3 | 6 | 6 | 1 | 2 | 1 | 0 | 0 | 19 | 5 |
| Over 0.50 inch | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 11 | 3 |
| Total | 0 | 0 | 1 | 14 | 49 | 102 | 105 | 91 | 42 | 3 | 1 | 0 | 408 | 100 |

[1] The "dry" thunderstorms listed were storms that passed directly over the station and from which no rain fell within a radius of at least 5 miles.

## THE WEATHER OF 1926 [1]

A summary of weather conditions in the United States for the year 1926 shows that, for the country as a whole, no marked unusual features as affecting agricultural interests were experienced. Conditions were rather unfavorable for development of some of the major crops, but were unusually favorable for others, with the general result as to yields satisfactory. More than half the country had for the year less than normal precipitation, more than normal warmth, and a longer than normal growing season.

The winter of 1925–26 had about normal temperature in all Southern States and in central and northern districts east of the Mississippi River, but was unusually mild throughout the Northwest. No low temperature records were broken; in fact, throughout practically all of the country the lowest reached during the winter ranged from 15° to as much as 50° above the previous low record. Precipitation was below normal over the greater part of the country. The spring season was generally cool and backward in much of the South and from the middle and upper Mississippi Valley eastward, but there was considerably more than normal warmth over the Northwest and quite generally west of the Rocky Mountains. Precipitation was heavy in the Southwest, but ranged from about normal to considerably below in other sections.

The summer had approximately normal temperature over the eastern half of the country and above normal over the western half. Precipitation was unevenly distributed, most sections east of the Mississippi River having more than the normal amount. For the fall season the temperature averaged slightly above normal in the South and generally so west of the Rocky Mountains, but somewhat below normal in most of the central valley and more northern States; precipitation was mostly light in the South and heavy in northern districts.

### YEAR GENERALLY WARMER THAN NORMAL

Chart I (A. J. H.) shows that the temperature for the year, as a whole, was below normal from the Mississippi River eastward, except in parts of the south Atlantic area, and generally above normal to the westward. From the Ohio Valley northward and eastward the deficiencies in temperature were large, but in the South they were small, with more than normal warmth reported in parts of the area. West of the Mississippi River, except locally in the Southwest, the year was abnormally warm, with the accumulated plus departures of temperature from normal in parts of the Northwest reaching more than 1,000°, or an average of nearly 3° a day. Approximately two-thirds of the country had a year warmer than normal.

In the Southwest and in most sections from the Mississippi Valley eastward the year had more than normal precipitation, although it was rather scanty in parts of the immediate Gulf section and over considerable sections of the Atlantic coast area, as shown by Chart II (A. J. H.). The greatest deficiencies in the East occurred in parts of New England and in Virginia and the Carolinas, where

[1] Reprinted from Weekly Weather and Crop Bulletin, Jan. 11, 1927.

some stations reported only about three-fourths of the normal annual fall. On the other hand, some upper Mississippi Valley districts had from 25 to nearly 50 per cent more than normal amount. The yearly totals were also in excess of normal in the southern border districts of the West and in most of California, but were below normal quite generally from the central and northern Great Plains westward, except in a few local areas. A little more than half the country had less than normal rainfall.

Chart III (not reproduced) shows for the year 1926 the departure from normal of the growing season, or the period between the dates of last killing frost in spring and the first in fall. It indicates that this was somewhat shorter than usual in most of the South and in Atlantic coast districts, and also in some central northern States, and locally in the far Northwest. In most of the central valleys the season of growth was somewhat longer than normal, and generally so over the West. The year had a longer than normal growing season in approximately 60 per cent of the country.

In the Atlantic States, there were 26 weeks warmer than normal, 25 cooler, and 1 exactly normal; 15 weeks with rainfall above normal, 30 below normal, and 7 just normal, with the annual precipitation 5.4 inches below normal. In the central area there were 29 warmer than normal weeks and 23 cooler than normal; 17 weeks with more than normal precipitation, 27 below normal, and 8 just normal, with the total precipitation 1.3 inches below normal. In the West, there were 35 weeks warmer and 17 cooler than normal; 15 weeks with more than normal precipitation, 29 with less than normal, and 8 just normal, with the annual amount 0.3 inch above normal.

THE YEAR'S WEATHER EFFECT ON CROPS

Wheat came through the mild winter with no material harm which, together with the subsequent favorable weather, resulted in an unusually good crop of the winter variety; likewise the general absence of damaging frost was responsible for one of the largest fruit yields in the history of the country, and the widespread favorable weather in the South gave an unprecedentedly large crop of cotton. Conditions were somewhat less favorable for corn, though the per-acre yield was only slightly below the preceding 10-year average, while heat and drought materially reduced the yield of spring wheat.

The general result of the year's weather effect on crop yields is indicated by the report of the Department of Agriculture showing the composite per-acre yield in percentage of the preceding 10-year average for the respective States. This indicates that the composite yield of all crops was below the 10-year average from the central Great Plains and lower and middle Mississippi Valley northward, slightly below in two South Atlantic States and Nevada, and generally above normal elsewhere. Of the 48 States, 34, comprising approximately two-thirds of the area of the country, had a composite yield of crops above the 10-year average.

*Cloudiness.*—A feature of the weather in northern districts, which also penetrated southward to include the middle Mississippi Valley, was the more than usual cloudiness. The annual average for the North Pacific Coast States, upper Mississippi Valley, upper and lower Lakes, and the Ohio Valley and Tennessee was more than 6 on a scale of 0–10.

The level of the Great Lakes in December, 1926, was higher than in the same month of 1915.

TABLE 1.—*Monthly and annual temperature departures, 1926*

| District | January | February | March | April | May | June | July | August | September | October | November | December | Average monthly departure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New England | +2.1 | −1.7 | −3.1 | −3.3 | −1.7 | −3.2 | −1.3 | −0.2 | −1.2 | −1.1 | +1.3 | −4.6 | −1.5 |
| Middle Atlantic | +0.9 | +0.2 | −3.4 | −2.5 | −0.4 | −3.1 | −0.1 | +1.3 | +0.4 | −0.7 | −0.5 | −3.4 | −0.9 |
| South Atlantic | −0.3 | +1.8 | −5.2 | −1.4 | −0.1 | −0.5 | +0.4 | +2.7 | +3.6 | +1.9 | −2.3 | +2.3 | +0.2 |
| Florida Peninsula | +0.2 | −0.9 | −2.9 | +0.5 | −1.0 | +0.4 | ±0.0 | +0.4 | +1.4 | +0.9 | −0.7 | +4.3 | +0.2 |
| East Gulf | −1.1 | +1.8 | −5.9 | −2.3 | −1.0 | −0.3 | −0.7 | +1.3 | +4.0 | +1.8 | −3.9 | +4.0 | −0.2 |
| West Gulf | −1.8 | +5.1 | −3.9 | −3.2 | −0.7 | −0.3 | −1.4 | +0.9 | +3.2 | +4.0 | −2.0 | +0.9 | +0.1 |
| Ohio Valley and Tennessee | −0.2 | +2.2 | −6.0 | −5.0 | +0.2 | −2.5 | +0.1 | +1.4 | +2.8 | ±0.0 | −3.0 | −1.0 | −0.9 |
| Lower Lakes | +1.3 | −0.8 | −4.9 | −6.0 | −2.3 | −4.5 | −1.2 | +1.0 | −0.9 | −2.1 | −0.2 | −4.4 | −2.1 |
| Upper Lakes | +2.0 | +2.4 | −5.0 | −4.7 | −0.2 | −4.1 | −0.6 | +0.6 | −2.3 | −2.6 | −3.0 | −4.0 | −1.8 |
| North Dakota | +12.0 | +14.8 | +3.6 | +2.2 | +4.6 | −2.7 | +1.8 | −0.4 | −4.9 | −0.2 | −4.1 | −2.6 | +2.0 |
| Upper Mississippi Valley | +3.6 | +7.2 | −4.2 | −4.3 | +2.6 | −3.4 | +0.4 | +1.3 | −1.0 | −1.0 | −3.8 | −2.6 | −0.4 |
| Missouri Valley | +4.3 | +10.2 | −0.9 | −2.1 | +4.6 | −1.2 | +1.1 | +2.0 | −1.7 | +0.9 | −3.8 | −0.9 | +1.0 |
| Northern slope | +5.4 | +11.0 | +3.1 | +2.6 | +3.2 | +1.2 | +2.3 | +0.5 | −6.0 | +3.1 | +0.2 | −1.9 | +2.1 |
| Middle slope | +2.2 | +8.4 | −2.4 | −3.5 | +2.2 | +0.1 | −0.5 | +1.8 | −0.7 | +2.3 | −0.6 | −1.1 | +0.7 |
| Southern slope | −2.0 | +6.3 | −3.9 | −5.2 | −1.4 | −0.4 | −2.5 | +0.8 | +2.1 | +3.7 | −0.1 | −0.5 | −0.3 |
| Southern Plateau | −1.3 | +3.5 | +1.8 | +1.6 | +0.6 | +2.4 | −0.4 | +0.9 | +2.0 | +3.2 | +2.6 | −1.5 | +1.3 |
| Middle Plateau | +1.1 | +4.9 | +2.9 | +5.2 | +2.9 | +5.3 | +1.5 | +1.2 | −1.5 | +2.7 | +4.9 | −0.9 | +2.5 |
| Northern Plateau | +1.3 | +8.1 | +3.6 | +5.9 | +1.4 | +4.4 | +4.3 | +0.8 | −4.7 | +2.2 | +3.9 | −0.9 | +2.5 |
| North Pacific | +2.9 | +5.8 | +5.6 | +6.8 | +2.8 | +3.7 | +2.6 | +1.3 | ±0.0 | +3.6 | +4.5 | +0.2 | +3.3 |
| Middle Pacific | −1.2 | +3.5 | +5.6 | +5.3 | +2.7 | +2.2 | +2.2 | +0.2 | −1.5 | +2.5 | +4.6 | −0.2 | +2.2 |
| South Pacific | +1.4 | +4.6 | +5.5 | +5.2 | +3.3 | +2.0 | +0.3 | +0.8 | −1.6 | +2.0 | +5.4 | −0.6 | +2.4 |
| UNITED STATES | +1.6 | +4.7 | −1.0 | −0.4 | +1.0 | −0.2 | +0.4 | +1.0 | −0.4 | +1.3 | ±0.0 | −0.9 | +0.6 |

TABLE 2.—*Monthly and annual precipitation departures, 1926*

| District | January | February | March | April | May | June | July | August | September | October | November | December | Accumulated departures for the year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New England | −0.7 | +0.7 | −1.1 | −0.7 | −1.0 | −0.7 | −0.5 | −0.4 | −1.3 | +1.7 | +0.9 | −0.5 | −3.6 |
| Middle Atlantic | ±0.0 | +0.5 | −1.5 | −1.2 | −1.3 | −1.4 | +0.2 | +1.2 | −0.2 | +0.1 | +1.1 | +0.4 | −2.1 |
| South Atlantic | +2.0 | −0.6 | +0.2 | −1.0 | −2.0 | +0.5 | −0.4 | −2.2 | −2.1 | −2.1 | +0.3 | −1.4 | −8.8 |
| Florida Peninsula | +2.5 | −1.9 | −0.2 | −0.7 | −0.2 | −2.0 | +2.0 | +4.4 | −1.0 | +0.4 | −0.9 | −1.5 | +0.9 |
| East Gulf | +2.7 | −2.5 | +0.9 | −1.2 | −0.2 | −0.4 | −0.1 | +1.6 | +1.1 | −0.5 | +1.0 | +0.3 | +2.7 |
| West Gulf | +0.4 | −1.7 | +2.6 | +0.7 | +0.1 | −0.8 | +0.6 | −0.9 | −1.4 | +1.0 | −1.5 | +2.3 | +1.4 |
| Ohio Valley and Tennessee | −0.1 | −0.6 | −1.3 | −0.9 | −1.4 | −1.6 | +0.3 | +2.5 | +1.8 | +1.8 | −0.4 | +2.0 | +2.1 |
| Lower Lakes | −0.5 | +0.1 | −0.4 | +1.2 | −1.8 | −0.3 | −1.0 | +2.0 | +2.8 | +1.8 | ±0.0 | −0.6 | +3.3 |
| Upper Lakes | −0.8 | +0.4 | +0.3 | −0.7 | −0.8 | +0.1 | −0.4 | −0.2 | +1.3 | +0.2 | +1.5 | −0.3 | +0.6 |
| North Dakota | −0.1 | −0.2 | −0.6 | −1.6 | −0.6 | −1.8 | −0.7 | −0.8 | +1.5 | −0.2 | ±0.0 | ±0.0 | −5.1 |
| Upper Mississippi Valley | −0.4 | −0.2 | −0.4 | −0.7 | −1.6 | −0.6 | −0.1 | +0.9 | +5.0 | +0.1 | +1.1 | −0.3 | +2.8 |
| Missouri Valley | +0.4 | −0.2 | −0.7 | −1.7 | −1.4 | −1.8 | −1.0 | +0.4 | +3.6 | +0.7 | +0.5 | −0.1 | −1.3 |
| Northern slope | −0.2 | −0.3 | −0.6 | −1.0 | ±0.0 | ±0.0 | −0.1 | +0.5 | +0.3 | −0.3 | +0.3 | −0.2 | −1.6 |
| Middle slope | +0.2 | −0.3 | +0.2 | −0.6 | −1.8 | −0.8 | +0.3 | −1.0 | +2.1 | +0.3 | −0.1 | +0.5 | −1.0 |
| Southern slope | +0.2 | −0.8 | +1.2 | +1.1 | −0.8 | +0.8 | −0.1 | −1.4 | +0.2 | +1.0 | −0.3 | +1.7 | +2.8 |
| Southern Plateau | −0.2 | −0.5 | +0.4 | +0.8 | +0.5 | −0.2 | −0.1 | −0.3 | +0.9 | ±0.0 | +0.4 | +1.3 | +3.0 |
| Middle Plateau | −0.4 | +0.1 | −0.6 | +0.3 | −0.3 | −0.3 | ±0.0 | −0.2 | −0.4 | −0.5 | +0.5 | +0.1 | −1.7 |
| Northern Plateau | −0.5 | +0.4 | −0.8 | −0.6 | −0.8 | −0.2 | −0.2 | +0.9 | +0.2 | −0.1 | +1.6 | −0.1 | −0.2 |
| North Pacific | −1.4 | +0.7 | −3.1 | −1.8 | +1.1 | −1.5 | −0.5 | +1.1 | −0.8 | +1.1 | +0.7 | −1.1 | −5.5 |
| Middle Pacific | +0.1 | +1.6 | −3.8 | +1.4 | −0.6 | −0.4 | ±0.0 | +0.2 | −0.5 | +0.3 | +4.2 | −1.8 | +0.8 |
| South Pacific | −0.8 | +0.9 | −2.3 | +4.2 | −0.5 | −0.1 | ±0.0 | ±0.0 | −0.2 | −0.4 | +2.5 | −0.4 | +2.9 |
| UNITED STATES | +0.1 | −0.1 | −0.6 | −0.2 | −0.7 | −0.6 | −0.1 | +0.4 | +0.6 | +0.3 | +0.6 | ±0.0 | −0.3 |

## NOTES, ABSTRACTS, AND REVIEWS

### C. G. ABBOT ON MONTEZUMA PYRHELIOMETRY [1]

Doctor Abbot has kindly consented to the advance publication by the Weather Bureau of the results of pyrheliometric observations made at Montezuma, Chile, from August 3, 1920, to April 30, 1926.

This advance publication is made in order that these important direct data of solar radiation may be available for study by meteorologists and other scientists at the earliest practicable moment. The 2½ pages of text recite simply the means that were taken to secure accuracy in the observations and the tabulation. The 12 pages of data are not discussed. This supplement, owing to the very technical character of the material presented, is not for general free distribution to the public, but copies may be had by students and others who wish to study the data on application to the Chief of the Weather Bureau.—*A. J. H.*

### W. PEPPLER "ON THE INFLUENCE OF THE FOEHN WIND UPON THE AVERAGE TEMPERATURE IN THE ALPINE FORELAND"

In a note on this subject (Met. Zeit., October, 1926, p. 374) it is shown that at some distance from the Alps the foehn has already lost most of its effectiveness at the surface, but is still very important aloft. The diminishing effect at the surface with increasing distance from the Alps is shown by the considerably greater frequency of the foehn at Bregenz at the southeast end of Lake Constance, where the northward opening Rhine Valley forms the channel for an important flow of foehn winds, than at Friedrichshafen on the north shore of the lake, where well-marked foehns occur only five times a year at the most.

An analysis of 69 cable-balloon ascents at Friedrichshafen, made when anticyclonic, cold-air masses lay at the surface, showed with few exceptions the existence of a warm foehn wind aloft overriding the cold lower stratum. For 52 such occasions the mean departure of temperature from the normal at given elevations (above sea level) were as follows:

| | | | |
|---|---|---|---|
| Below 400 m. | 500 m. | 1,000 m. | |
| 2.3° C. | 3.1° | 5.1° | (max. departure). |

Above 1,000 m. the departures declined to 2° at 3,000 m. (28 observations). This places the maximum departure at 600 m. above the surface of Lake Constance.

It is pointed out that this overrunning foehn should show an ameliorating effect on climate at elevations of some 600–800 m. in the Alpine foothills and even in the southern Black Forest; in this connection E. Wimmer is quoted as ascribing to the foehn the especially vigorous growth of the copper beech at these altitudes in the Feldberg area.

The importance of the Alps as a barrier to the southward escape of cold-air masses, and hence as a primary cause of the failure of the foehn to be felt at the lower elevations far north of the mountains, is emphasized. The consequence is that the cold-air masses exert a compensating influence which more than offsets the tendency of the foehn to raise the mean temperatures at low elevations.—*B. M. V.*

### RETIREMENT OF DOCTOR DORNO

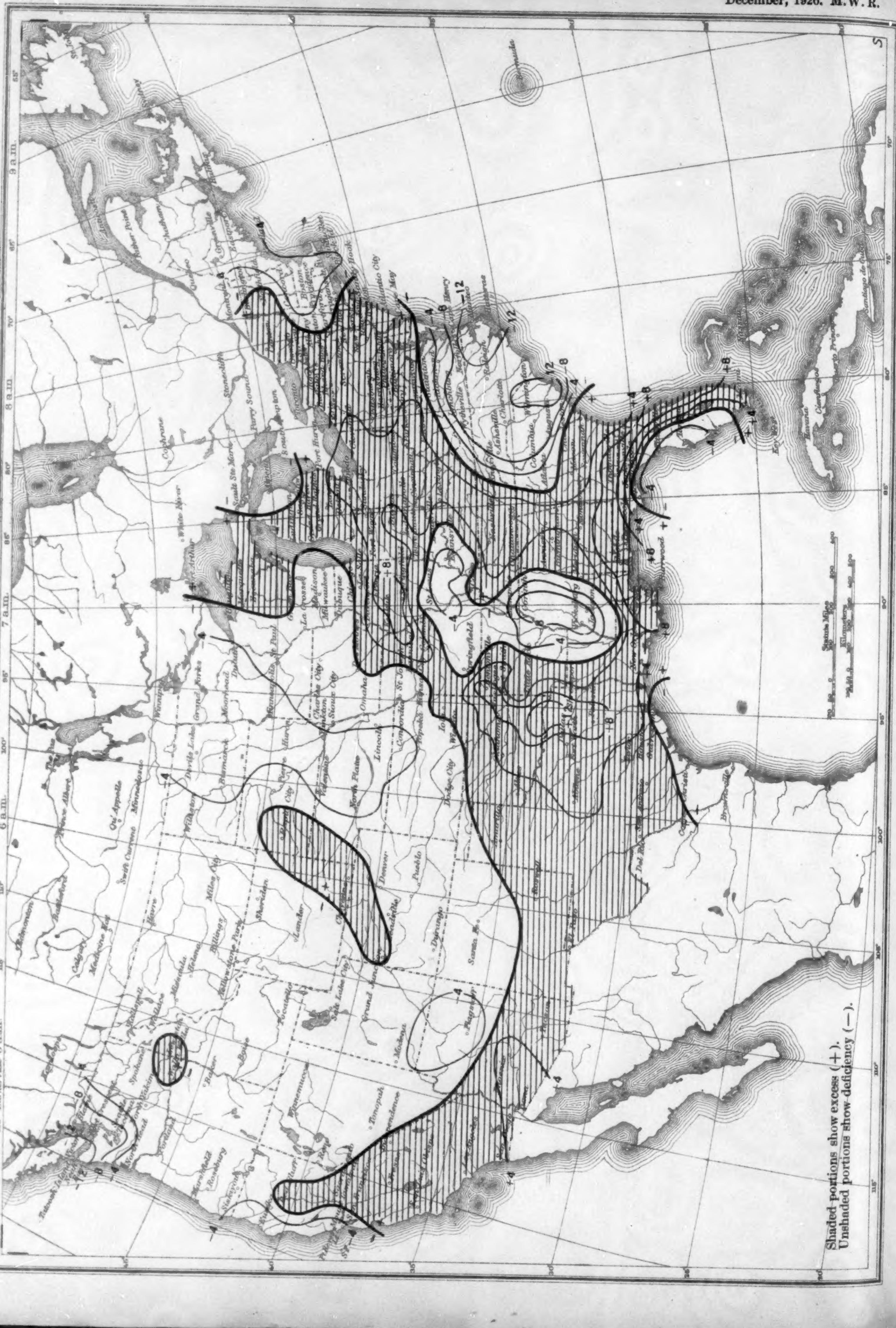
Dr. C. Dorno has sent word that on October 1, 1926, he resigned the directorship of the Physical-Meteorological Observatory at Davos. He founded the observatory and brought it to a position of unique eminence in its field.

His successor is Dr. F. Lindholm, who was long associated with the elder Ångström and who, previous to his present appointment, was State meteorologist in charge of the forecast division of the Swedish meteorological office.—*B. M. V.*

[1] Abbot, C. G., Montezuma Pyrheliometry, MONTHLY WEATHER REVIEW SUPPLEMENT No. 27, Washington, D. C., December, 1926.

A. J. H. I. Annual Temperature Departures (°F.) in the United States, 1926

A. J. H. II. Annual Precipitation Departures (inches) in the United States, 1926



## SOLAR RADIATION AND THE TEMPERATURE IN THE CENTRAL ZONE OF CHILE

(A note received from Señor J. Bustos Navarrete, Director, Observatorio del Salto, Santiago)

El Salto Observatory has just completed a new scientific investigation of the relation between solar radiation and the annual march of temperature in the central zone of Chile.

Two comparative studies are discussed, one on the solar radiation and temperature from 1905 to 1925, the other on solar activity and the temperature from 1889 to 1925.

The conclusions reached in this work are of notable interest. It has been found that the minima of solar activity precede, without exception, minima of temperature. On the other hand, the periods of intense solar activity coincide with the series of relatively warm years * * *.

Moreover, in an earlier work of the Observatorio del Salto, entitled "Solar Radiation and the Rains in the Central Zone of Chile from 1850 to 1925," there has been found a clear relation between those two phenomena.

## V. BJERKNES ON THE THEORY OF SUNSPOTS

(Reprint from Nature, December 18, 1926)

An important contribution to the theory of sun spots and the sun's general circulation is made by Prof. V. Bjerknes in the Astrophysical Journal, September, 1926, under the title "Solar Hydrodynamics." For the details of the theory reference must be made to the paper in question, but a short outline of the main points may be given as follows. On the assumption that a sun spot is a vortex decreasing in intensity from the photosphere downward, their low temperatures are explained from general hydrodynamical and thermodynamical principles.

The results deduced are in accordance with the accepted temperatures of sun spots and the probable velocities of the gases involved in the vortex. A preliminary account of this part of Bjerknes's investigation was given in Nature, March 27, page 463. The well-known properties of sun spots (their usual occurrence in pairs having opposite magnetic polarities, the progression of the spot zones toward the equator during the 11-year cycle, the magnetic-polarity cycle of 22 years, etc.) are explained by making the following suppositions. In each of the sun's hemispheres, northern and southern, there are two zonal vortices having opposite rotations and surrounding the sun approximately as parallels. Wherever part of either vortex rises and cuts the photosphere, a typical bipolar pair of sun spots makes its appearance. As part of a scheme of general circulation, these two zonal vortices revolve around each other in a period of 22 years, being brought alternately near to the surface of the photosphere in latitudes about 40°, progressing equatorward in the course of 11 years, and descending again into the interior near the sun's equator. The scheme of general circulation is one demanding a condition of what is known as stratified circulation.

Renewed investigations are required on the part of observers to determine any possible systematic movements which may be shown by sun spots, faculæ, calcium, and hydrogen flocculi, and prominences. The systematic drifts suggested by the theory are apparently too slow to be observed spectroscopically (cf. Astrophysical Journal, 32, 80, 1910, where St. John compares the mean wave length of $K_2$ and $K_3$ near the sun's poles and at the equator for detection of systematic movements).

Professor Bjerknes's paper is also discussed, together with remarks bearing on the question of observed systematic motions of spots and faculæ, by "W. M. H. G." and "H. W. N." in the Observatory for December.

## THE BRÜCKNER CYCLE IN THE UNITED STATES

(Author's abstract of a paper read before American Meteorological Society, Philadelphia meeting, December, 1926)

By ALFRED J. HENRY

The Brückner cycle of climatic changes, so called from its discoverer, Dr. E. Brückner, postulates that groups of cold and wet, warm and dry years succeed each other in a cycle or period having an average length of 35 years; the length of the period, however, may be only 20 years or as many as 50 years. One half of the period tends to be cool and rainy, while the other half tends to be warm and dry.

The range from low to high temperatures is small, on the average not more than 1° C. (1.8 F.), as shown by five-year averages of the annual mean temperature.

The range in rainfall from wet to dry years, and vice versa, is also small, not to exceed 10 per cent above or below the mean—five-year averages considered.

Brückner reached his results from a consideration of five-year averages of temperature and precipitation as recorded at 321 stations scattered over the globe, most of which, however, were in Europe and North America. He also considered changes in the level of the waters of inland seas, lakes, and rivers, the time of grape harvest in Europe, the advance and retreat of glaciers, etc. From all of these different lines of evidence he concluded that a cycle of 35 years on the average best fitted the evidence.

Since a great many more meteorological stations are now in operation than in 1890, when Brückner published his results. I have recomputed the five-year averages of precipitation for the United States, 1826 to 1920, inclusive, with a view to determining whether or not the oscillations therein agree with those scheduled to occur in a 35-year cycle. In 1923 I computed and published the annual mean temperature for the United States as a single geographic unit for each year of the nineteenth century.

The results of an examination of these data show that both temperature and precipitation oscillate up and down in an irregular manner, but on the average in intervals of 7 to 10 years, counting from maximum to maximum or minimum to minimum. In extreme cases the interval may be as long as 22 years and longer if one considers only the changes of great amplitude; there is, moreover, a lack of uniformity in the distribution of warm and cold, wet and dry years which increases as the area under consideration increases.

Dry years are much more frequent in the United States, and doubtless other countries, than wet ones. Abundant rains were quite general in all parts of the country in the early eighties; since that time, although heavy rains have occurred in parts of the country, as in the Ohio Valley in 1913, the lower Missouri Valley in 1903, 1915, and again in September of the current year, there have been no uniformly wet years in this country.

The known distribution of precipitation the world over teaches us not to expect years of heavy rains concurrently in all parts of the world, but rather that heavy rains may occur in the same year in widely separated parts of the world. The present year seems to have been one of that character.

## METEOROLOGICAL SUMMARY FOR SOUTHERN SOUTH AMERICA, NOVEMBER, 1926

By Sr. J. BUSTOS NAVARRETE, Director

[Observatorio del Salto, Santiago, Chile]

November had a more active atmospheric circulation, which culminated in the development of great storms over the southern zone of Chile during the closing days of the month.

Between the 1st and 4th a somewhat important depression crossed the far southern part of the continent, causing rains in the south and as far north as the coast of Arauco. Daily precipitation did not exceed 10 mm.

On the 5th the pressure rose, causing an important anticyclonic center over the south, with fall of temperature and general fine weather until the 8th.

On the 9th and 10th a strong depression crossed the far southern region, causing rains as far north as Valdivia and heavy snows in the region of Magallanes.

From the 11th to the 19th atmospheric quiet reigned over the south, the center of high pressure frequently extending from Chiloe to the island of Huafo. However, during the 16th and 17th electrical storms developed in the interior of Biobio, Malleco, and Arauco Provinces and on Isla Mocha. These storms moved clear across the country.

On the 20th began a period of bad weather in southern Chile. Between the 20th and 23d a depression crossing the far south caused rains as far as Valdivia. Between the 24th and 30th great cyclones followed one another across the far south, causing heavy rain and wind storms which lashed the entire region as far up as Concepcion Province. On the 28th in the early morning the wind velocity reached more than 1,000 m. per minute (37.1 m. p. h.) at Valdivia. Precipitation varied on the average between 10 and 30 mm. * * *—*Transl. B. M. V.*

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# SOLAR OBSERVATIONS

## SOLAR AND SKY RADIATION MEASUREMENTS DURING DECEMBER, 1926

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1924, **52** : 42, January, 1925, **53** : 29, and July, 1925, **53** : 318.

From Table 1 it is seen that solar radiation intensities averaged slightly above the normal for December at Washington, D. C., and Lincoln, Nebr., and close to normal at Madison, Wis.

Table 2 shows a deficiency for the month at the abovenamed stations in the amount of radiation received on a horizontal surface from the sun and sky. It also shows a deficiency at these three stations for the year, amounting to 1.7 per cent at Washington, 2.2 per cent at Madison, and 2.8 per cent at Lincoln.

Skylight polarization measurements made on three days at Washington give a mean of 65 per cent, with a maximum of 66 per cent on the 2d. These are slightly above the corresponding average values for December at Washington. No sky polarization measurements were made at Madison, as the ground was covered with snow throughout the month.

TABLE 1.—*Solar radiation intensities during December, 1926*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

| Date | Sun's zenith distance: 8 a.m. | 78.7° | 76.7° | 70.7° | 60.0° | 0.0° | 60.0° | 70.7° | 75.7° | 78.7° | Noon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 75th mer. time | Air mass, A. M. | | | | | P. M. | | | | Local mean solar time |
| | e. | 5.0 | 4.0 | 3.0 | 2.0 | *1.0 | 2.0 | 3.0 | 4.0 | 5.0 | e. |
| | mm. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | mm. |
| Dec. 2 | 1.78 | 1.01 | 1.12 | 1.25 | 1.40 | 1.58 | ...... | 1.17 | 0.99 | 0.89 | 1.88 |
| 6 | 1.60 | 0.98 | 1.12 | 1.26 | 1.42 | 1.60 | ...... | 1.16 | 1.07 | 0.96 | 1.78 |
| 14 | 7.04 | ...... | ...... | ...... | ...... | ...... | ...... | 0.97 | 0.83 | 0.73 | 3.99 |
| 16 | 1.12 | 0.85 | 0.97 | 1.17 | 1.35 | 1.57 | ...... | 1.20 | ...... | ...... | 1.07 |
| 17 | 1.88 | | ...... | ...... | ...... | | ...... | ...... | 0.99 | ...... | 1.88 |
| 18 | 0.81 | 0.90 | 1.01 | 1.16 | 1.40 | ...... | ...... | 1.19 | 1.01 | 0.78 | 1.78 |
| 23 | 3.45 | 0.50 | 0.70 | 0.85 | ...... | ...... | ...... | ...... | ...... | ...... | 2.87 |
| 29 | 4.37 | ...... | ...... | 0.87 | ...... | ...... | ...... | ...... | ...... | ...... | 3.15 |
| 30 | 2.16 | 0.68 | 0.84 | 1.04 | 1.20 | 1.38 | ...... | 1.04 | 0.84 | 0.68 | 1.96 |
| Means | ...... | 0.82 | 0.96 | 1.09 | 1.35 | 1.53 | ...... | 1.12 | 0.96 | 0.81 | ...... |
| Departures | ...... | +0.04 | +0.07 | +0.04 | +0.12 | ...... | ...... | +0.10 | +0.06 | +0.03 | ...... |

* Extrapolated.

TABLE 1.—*Solar radiation intensities during December, 1926*—Con.

Madison, Wis.

| Date | Sun's zenith distance: 8 a.m. | 78.7° | 75.7° | 70.7° | 60.0° | 0.0° | 60.0° | 70.7° | 75.7° | 78.7° | Noon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 75th mer. time | Air mass, A. M. | | | | | P. M. | | | | Local mean solar time |
| | e. | 5.0 | 4.0 | 3.0 | 2.0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | e. |
| | mm. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | mm. |
| Dec. 1 | 1.96 | ...... | 1.18 | 1.31 | ...... | ...... | ...... | ...... | ...... | ...... | 1.52 |
| 14 | 0.43 | 1.08 | 1.16 | 1.29 | ...... | ...... | ...... | ...... | ...... | ...... | 0.58 |
| 15 | 0.51 | 0.92 | 1.12 | 1.23 | ...... | ...... | ...... | 1.18 | ...... | ...... | 0.74 |
| 24 | 0.74 | ...... | ...... | ...... | ...... | ...... | ...... | 1.25 | ...... | ...... | 0.58 |
| 29 | 0.81 | 1.09 | 1.18 | 1.30 | ...... | ...... | ...... | ...... | ...... | ...... | 1.19 |
| 30 | 2.16 | 0.79 | 0.90 | 1.03 | ...... | ...... | ...... | ...... | ...... | ...... | 3.30 |
| Means | ...... | 0.97 | 1.11 | 1.23 | ...... | ...... | ...... | 1.22 | ...... | ...... | ...... |
| Departures | ...... | +0.01 | +0.01 | +0.01 | ...... | ...... | ...... | −0.06 | ...... | ...... | ...... |

Lincoln, Nebr.

| Date | 8 a.m. | 78.7° | 75.7° | 70.7° | 60.0° | 0.0° | 60.0° | 70.7° | 75.7° | 78.7° | Noon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec. 13 | 0.74 | ...... | ...... | ...... | ...... | ...... | | 1.30 | 1.18 | 1.08 | 0.56 |
| 14 | 0.51 | 1.11 | 1.20 | 1.34 | 1.49 | 1.66 | ...... | 1.30 | ...... | ...... | 0.64 |
| 20 | 3.63 | 0.81 | 0.94 | 1.18 | ...... | ...... | ...... | ...... | ...... | ...... | 3.81 |
| 25 | 1.88 | ...... | 1.15 | 1.27 | ...... | 1.56 | ...... | ...... | 1.17 | 1.06 | 2.62 |
| 28 | 2.26 | ...... | ...... | ...... | ...... | ...... | ...... | 1.24 | 1.12 | 0.99 | 2.36 |
| 29 | 2.16 | ...... | 0.98 | 1.11 | ...... | ...... | ...... | ...... | 0.97 | 0.86 | 3.30 |
| 30 | 2.74 | 1.04 | 1.16 | 1.30 | ...... | 1.57 | ...... | ...... | 1.16 | 1.02 | 3.63 |
| Means | ...... | 0.99 | 1.09 | 1.24 | 1.49 | 1.60 | ...... | 1.28 | 1.12 | 1.00 | ...... |
| Departures | ...... | +0.05 | +0.03 | +0.01 | +0.11 | ...... | ...... | +0.07 | +0.04 | +0.03 | ...... |

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

| Week beginning— | Average daily radiation: Washington | Madison | Lincoln | Chicago | New York | Average daily departure from normal: Washington | Madison | Lincoln |
|---|---|---|---|---|---|---|---|---|
| 1926 | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. |
| Dec. 3 | 98 | 92 | 105 | 38 | 99 | −48 | −29 | −71 |
| 10 | 118 | 123 | 183 | 93 | 78 | −25 | ± 0 | +11 |
| 17 | 115 | 78 | 141 | 57 | 105 | −28 | −49 | −33 |
| 24* | 116 | 128 | 190 | 67 | 85 | −30 | −4 | +12 |
| Deficiency at end of year | | | | | | −2,135 | −2,594 | −3,908 |

* 8-day mean.

# WEATHER OF NORTH AMERICA AND ADJACENT OCEANS

## NORTH ATLANTIC OCEAN

By F. A. YOUNG

There was a great difference in the weather conditions over the western and eastern divisions of the North Atlantic during the month, as over the western section the number of days with gales was either near or above the normal, the maximum number occurring in the 5-degree square between the 40th and 45th parallels and the 55th and 60th meridians, where they were reported on ten days. East of the 30th meridian, however, there was a sharp decline in the number; reports to date have not shown more than three gales in any one square in this region, where anticyclonic conditions were unusually prevalent.

The number of days with fog was apparently considerably below the normal over the Grand Banks and slightly above over the middle and eastern sections of the steamer lanes, while it was observed on two days in the Gulf of Mexico.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (75th meridian), North Atlantic Ocean, December, 1926*

| Stations | Average pressure | Departure [1] | Highest | Date | Lowest | Date |
|---|---|---|---|---|---|---|
| | Inches | Inch | Inches | | Inches | |
| Julianehaab, Greenland | [2] 29.47 | ([3]) | 30.54 | 25th | 28.71 | 6th. |
| Belle Isle, Newfoundland. | 29.74 | +0.04 | 30.48 | 5th | 28.94 | 20th. |
| Halifax | 29.91 | −0.07 | 30.46 | 5th | 29.44 | 29th. |
| Nantucket | 30.03 | −0.05 | 30.52 | 5th | 29.52 | 29th. |
| Hatteras | 30.13 | −0.01 | 30.56 | 19th | 29.58 | 11th. |
| Key West | 30.09 | 0.00 | 30.24 | 30th | 29.94 | 12th.[4] |
| New Orleans | 30.13 | +0.01 | 30.46 | 30th | 29.74 | 13th. |
| Swan Island | 29.91 | −0.07 | 30.00 | 30th [4] | 29.80 | 13th. |
| Turks Island | 30.08 | +0.05 | 30.16 | 26th [4] | 30.00 | 2d.[4] |
| Bermuda | 30.14 | −0.01 | 30.36 | 8th [4] | 29.82 | 2d. |
| Horta, Azores | 30.23 | +0.12 | 30.70 | 3d | 29.74 | 19th. |
| Lerwick, Shetland Islands. | 29.99 | +0.27 | 30.96 | 24th | 29.22 | 17th. |
| Valencia, Ireland | 30.43 | +0.49 | 30.89 | 24th | 30.07 | 4th. |
| London | 30.31 | +0.29 | 30.70 | 23d | 29.82 | 3d. |

[1] From normals shown on H. O. Pilot Chart based on observations at Greenwich mean noon, or 7 a. m., 75th meridian.
[2] Mean of 22 observations—nine days missing.
[3] No normal established.
[4] And on other dates.

The unusually large positive departure at the stations on the British Isles was due to periods of abnormally high pressure that will be referred to later. The lowest reading at Valencia was 0.13 inch above the monthly normal for that station.

At the time of observation on the 1st, moderate conditions prevailed over practically the entire ocean. Later in the day, however, a depression appeared off the American coast that on the 2d and 3d was in the vicinity of Nova Scotia and Newfoundland, respectively. On the 2d, New York reported wind southwest, force 9, and on the 3d moderate to strong gales were encountered by vessels between the 35th and 45th parallels and 55th and 65th meridians. On the 4th the storm area covered the territory between the 40th and 50th parallels and the 30th and 45th meridians. From the 2d to 4th an area of low pressure was over the North Sea, where moderate weather prevailed, although on the 4th northwest gales were reported in the English Channel.

On the 5th, St. Johns, Newfoundland, was near the center of a LOW, while unusually high pressure prevailed off the New England coast, the barometer at Portland reading 30.70 inches. Strong southwesterly gales, accompanied by comparatively high barometric readings, were reported by vessels between the 40th parallel and Newfoundland. On the same day there was a disturbance of limited extent and intensity in southern waters, as shown by report in table from the Japanese S. S. *Keifuku Maru*.

The pressure then fell rapidly along the American coast, and on the 6th a well-developed LOW was central about 200 miles south of Halifax, with heavy winds of various directions west of the 55th meridian, while westerly gales were also reported over the middle sections of the steamer lanes. The northern disturbance moved slowly northeastward, and on the 7th was central near St. Johns, Newfoundland, while the storm area now covered the region between the 50th and 70th meridians, extending as far south as the Bermudas.

On the 8th southerly gales prevailed over the steamer lanes between the 20th and 35th meridians, and northerly winds, force 7, between the 30th and 40th parallels and 50th and 55th meridians.

On the 9th St. Johns was again near the center of a moderate depression that moved rapidly eastward, and on the 11th was central near 50° N., 40° W. On the 11th there was also a LOW near Hatteras; it increased in intensity as it moved northeastward along the coast, its center reaching the vicinity of Sable Island by the 12th.

From the 9th to 11th gale reports were received from vessels in widely scattered positions, while on the 12th the storm area was confined to the region between the 30th and 50th parallels, west of the 45th meridian. During this period anticyclonic conditions prevailed over the eastern section of the steamer lanes, and on the 11th barometric readings of slightly over 30.70 inches were recorded at stations in the British Isles.

From the 13th to 17th there were no well-defined storm areas, although during this period reports of moderate gales were received from vessels in different sections of the ocean.

On the 18th a shallow depression was over the west coast of Newfoundland that moved but slightly during the next 48 hours, although increasing in intensity, as on the 19th strong northwesterly gales prevailed between the 35th and 50th parallels, west of the 55th meridian, while by the 20th the storm area had contracted considerably in extent.

On the 19th there was also a moderate LOW off the northern coast of Scotland, which by the 20th had moved over the North Sea, where moderate southwesterly gales occurred.

On the 21st Belle Isle was near the center of a LOW, although moderate weather conditions were the rule in that vicinity as well as over the greater part of the ocean.

Charts VIII to XI cover the period from the 22d to 25th, inclusive, and give an idea of the area of high pressure that spread over the coast of Europe, reaching its maximum on the 24th, when the barometer at Stornoway, Scotland, read 31.03 inches. These charts also show the disturbance that on the 22d was central near 42° N., 45° W.

On the 26th a LOW was off the Virginia Capes, with moderate southwest gales west of the 65th meridian, that moved rapidly eastward, and on the 27th was central near 43° N., 53° W. On that date winds of force 7 and 8 occurred along the 40th parallel, between the 40th and 60th meridians. On the 26th southerly gales were also reported between the Azores and the 35th meridian, accompanied by comparatively high barometric readings.

On the 29th a well-developed depression was central near Eastport, Maine, with southerly gales between Nova Scotia and the 35th parallel. On the 30th the center of this LOW was near Belle Isle, and on the 31st near 53° N., 45° W. On the former date southeasterly gales were encountered in the vicinity of the Azores, and on the latter, the storm area covered the region between the 35th and 55th parallels and the 30th and 45th meridians.

*Ocean gales and storms, December, 1926*

| Vessel | Voyage | | Position at time of lowest barometer | | Gale began | Time of lowest barometer | Gale ended | Lowest barometer (Ins.) | Direction of wind when gale began | Direction and force of wind at time of lowest barometer | Direction of wind when gale ended | Highest force of wind and direction | Shifts of wind near time of lowest barometer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | From— | To— | Latitude | Longitude | | | | | | | | | |
| **NORTH ATLANTIC OCEAN** | | | ° ′ | ° ′ | | | | | | | | | |
| West Harcuvar, Am. S. S. | Norfolk | Hamburg | 39 39 N. | 69 50 W. | Dec. 1 | 2 a., 1 | Dec. 4 | 29.59 | NW | NW., 6 | Var | NW., 10 | NW.-SW. |
| Bellflower, Am. S. S. | Liverpool | Boston | 37 26 N. | 61 15 W. | 2 | 4 a., 2 | 3 | 29.50 | SSW | SSW., 6 | NW | W., 10 | |
| Englewood, Am. S. S. | Savannah | Bremen | 51 42 N. | 2 55 E. | 3 | —, 4 | 5 | 29.63 | NW | NW., 8 | N | NW., 9 | N.-W. |
| Ocean Prince, Br. S. S. | Antwerp | Newport News. | 46 07 N. | 40 42 W. | 3 | 8 a., 4 | 4 | 29.84 | S | WSW., 8 | NW | SW., 9 | WSW.-NW. |
| Silvercedar, Br. M. S. | Gibraltar | New York | 38 01 N. | 71 41 W. | 5 | 11 p., 5 | 6 | 29.82 | SW | WNW., 11 | NNW | NW., 12 | SW.-NW. |
| Keifuku Maru, Jap. S. S. | Canal Zone | Falmouth | 29 03 N. | 49 05 W. | 4 | 9 a., 5 | 6 | 29.82 | ESE | SW., 8 | SSW | SE., 9 | ESE.-SSW. |
| California, Dan. M. S. | Bahia | Copenhagen | 36 11 N. | 15 50 W. | 5 | 10 p., 5 | 8 | 30.17 | NNE | NNE., 6 | NNE | NNE., 9 | Steady. |
| New York City, Br. S. S. | Bristol | New York | 42 40 N. | 63 23 W. | 6 | 3 p., 6 | 7 | 28.78 | ESE | SW., 10 | NW | SW., 10 | SSW.-WSW. |
| Tosari, Du. S. S. | Port Said | Boston | 43 25 N. | 58 55 W. | 5 | 7 a., 6 | 7 | 29.27 | S | SW., 11 | NNW | SW., 11 | SW.-W. |
| Padnsay, Am. S. S. | Charleston | Santa Cruz | 30 49 N. | 49 53 W. | 7 | 7 p., 8 | 8 | 29.64 | NNW | N., 10 | NE | N., 10 | NW.-N.-NE. |
| Boston City, Br. S. S. | Bristol | Philadelphia | 50 15 N. | 32 00 W. | 8 | 4 p., 8 | 8 | 29.94 | SSW | SSW., — | WNW | SSW., 9 | SW.-NW. |
| Chenab, Br. S. S. | Baltimore | Dublin | 41 20 N. | 42 00 W. | 9 | 11 a., 10 | 10 | 29.41 | ENE | SSE., 12 | E | SSE., 12 | SE.-SSE. |
| Collegian, Br. S. S. | Liverpool | Newport News. | 36 21 N. | 63 20 W. | 11 | Mdt., 11 | 13 | 29.39 | SW | WNW., 10 | WNW | NW., 10 | SW.-WNW. |
| Ariano, Br. S. S. | Halifax | London | 48 20 N. | 38 00 W. | 10 | 7 p., 11 | 11 | 29.28 | S | S., 9 | SW | S., 9 | S.-SW. |
| Caucasier, Bel. S. S. | New York | Antwerp | 41 00 N. | 61 00 W. | 11 | 4 a., 12 | 13 | 28.65 | E | SW., 3 | W | WNW., 10 | E.-S.-W. |
| Samland, Bel. S. S. | Antwerp | New York | 44 25 N. | 54 10 W. | 12 | 2 a., 12 | 13 | 29.14 | SSE | SW., 10 | WNW | SW., 11 | SW.-W. |
| American Trader, Am. S. S. | London | do | 43 30 N. | 57 45 W. | 18 | Mdt., 18 | 20 | 29.56 | WSW | WSW., 10 | NW | NW., 10 | WSW.-NW. |
| Cyrus Field, Br. Cable S. S. | Halifax (near) | | 46 46 N. | 56 14 W. | 19 | Mdt., 19 | 20 | 29.26 | NNW | WSW., 9 | WNW | WSW., 9 | WNW.-W.-WSW. |
| Maine, Dan. S. S. | Copenhagen | Portland (Me.). | 59 33 N. | 6 44 W. | 19 | 2 a., 20 | 20 | 29.58 | W | W., 11 | N | W. 11 | W.-NW.-N. |
| Sylvafield, Br. M. S. | Colon | London | 35 01 N. | 46 45 W. | 21 | 10 p., 21 | 22 | 29.33 | WSW | WSW., 7 | WNW | WSW., 10 | S.-W.-WNW. |
| Galtymore, Br. S. S. | Liverpool | Boston | 51 25 N. | 21 25 W. | 21 | Mdt., 21 | 22 | 29.83 | SSE | SSE., 8 | NW | SSE., 9 | SSE.-NW. |
| Athelmere, Br. S. S. | Curacao | Hamburg | 37 28 N. | 41 15 W. | 21 | 2 p., 22 | 23 | 29.37 | SSW | W., 8 | WSW | —, 10 | SW.-W. |
| Wytheville, Am. S. S. | Rotterdam | New York | 35 00 N. | 55 16 W. | 21 | 4 a., 23 | 24 | 29.42 | SW | NNE., 5 | NNW | NNW., 12 | NW.-ESE.-NW. |
| Bolivian, Br. S. S. | Liverpool | Kingston | 42 57 N. | 28 20 W. | 23 | —, 23 | 26 | 29.73 | S | S., — | SSE | SSW., 10 | SSW.-SSE. |
| Nieuw Amsterdam, Du. S. S. | New York | Rotterdam | 46 05 N. | 36 24 W. | 24 | 5 a., 24 | 25 | 29.13 | SSE | SSE., 7 | S | SSE., 9 | Steady. |
| Wytheville, Am. S. S. | Rotterdam | New York | 36 33 N. | 66 41 W. | 25 | 1 p., 26 | 27 | 29.63 | WSW | SW., 12 | N | SW., 12 | SW.-W.-N. |
| Bremen, Ger. S. S. | Bremerhaven | do | 43 47 N. | 53 58 W. | 27 | 8 a., 27 | 27 | 29.11 | SE | NNW., 6 | SW | NW., 10 | WSW.-W.-NW |
| Inverurie, Br. S. S. | Tampico | Southampton | 37 41 N. | 61 43 W. | 28 | Mdt., 29 | 29 | 29.76 | S | SW., — | NNW | SSW., 9 | WSW.-NW. |
| River Tigris, Br. S. S. | Gibraltar | New York | 36 30 N. | 62 49 W. | 29 | 4 a., 30 | 30 | 29.79 | S | S., — | N | —, 9 | |
| Breedijk, Du. S. S. | Rotterdam | do | 45 33 N. | 42 07 W. | 31 | Noon, 31 | 31 | 29.55 | S | S., 9 | NNW | S., 10 | S.-WSW.-NNW. |
| **NORTH PACIFIC OCEAN** | | | | | | | | | | | | | |
| Lubrico, Am. S. S. | San Pedro | Point Wells, Wash. | 48 18 N. | 125 10 W. | Nov. 30 | 6 p., 1st | Dec. 1 | 29.31 | SE | S., 8 | S | NW., 9 | S.-NW. |
| Akagisan Maru, Jap. S. S. | Yokohama | San Francisco | 47 50 N. | 161 45 W. | Dec. 1 | 4 p., 2 | 3 | 28.59 | ESE | N., 10 | WNW | NNW., 11 | NNE.-N. |
| Taiho Maru, Jap. S. S. | Miike | Vancouver | 42 41 N. | 169 36 E. | 1 | 8 p., 1 | 3 | 29.23 | WNW | WNW., 10 | NW | WNW., 10 | |
| Volunteer, Am. S. S. | Honolulu | Kobe | 32 27 N. | 141 42 E. | 1 | 9 a., 2 | 3 | 29.93 | S | SW., 9 | NW | SW., 9 | S.-W.-NW. |
| Pres. Polk, Am. S. S. | do | do | 29 10 N. | 177 20 W. | 1 | 2 p., 1 | 3 | 29.67 | SW | WNW., 9 | NW | WNW. 9 | WNW.-NW. |
| Hakutatsu Maru, Jap. S. S. | Portland | Yokohama | 43 39 N. | 153 40 E. | 2 | 4 a., 3 | 3 | 29.18 | SE | SSW., 6 | W | SE., 10 | |
| Wheatland Montana, Am. S. S. | Vancouver | do | 52 26 N. | 161 00 W. | 2 | 1 a., 3 | 4 | 28.40 | ESE | S., 4 | W | NE., 10 | NE.-S. |
| Las Vegas, Am. S. S. | Otaru | San Pedro | 43 15 N. | 141 02 E. | 3 | 5 p., 3 | 5 | 29.68 | W | WNW., 10 | WNW | WNW., 10 | W.-WNW. |
| Steel Age, Am. S. S. | Formosa | Port Townsend. | 26 10 N. | 124 08 E. | 4 | 6 p., 5 | 5 | 29.82 | E | SSE., — | S | SE., 9 | S.-SW. |
| La Crescenta, Br. S. S. | Newchwang | San Pedro | 38 42 N. | 179 02 W. | 2 | 11 p., 3 | 7 | 29.41 | NW | NW., 8 | SSE | NW., 10 | Steady. |
| Levant Arrow, Am. S. S. | Nagasaki | do | 36 00 N. | 172 00 E. | 2 | 4 p., 6 | 8 | 29.39 | SSE | WNW., 11 | N | WNW., 12 | W.-NW. |
| Pres. Madison, Am. S. S. | Yokohama | Victoria | 46 45 N. | 170 00 E. | 4 | 12 p., 7 | 9 | 29.72 | NW | NW., 7 | NNE | —, 11 | NW.-N.-NNE. |
| Hayo Maru, Jap. S. S. | Miike | Vancouver | 48 37 N. | 160 52 W. | 6 | 4 p., 6 | 7 | 28.65 | E | SE., 8 | SSW | S., 9 | |
| Taiho Maru, Jap. S. S. | do | do | 48 32 N. | 163 41 W. | 6 | 8 p., 6 | 7 | 28.25 | E | SSE., — | S | —, 11 | South. |
| Kureha Maru, Jap. S. S. | do | Seattle | 50 03 N. | 160 12 W. | 6 | 1 a., 7 | 8 | 28.53 | E | SSW., 10 | WSW | SSW., 10 | S.-SW. |
| Shabonee, Br. S. S. | San Pedro | Nagasaki | 26 36 N. | 177 31 W. | 5 | 4 a., 6 | 9 | 29.57 | SW | W., 8 | NW | NNW., 12 | WSW.-WNW |
| Stockton, Am. S. S. | Cebu | Portland | 38 50 N. | 159 52 E. | 7 | 1 p., 7 | 8 | 29.36 | SSE | SSE., 7 | SW | S., 10 | SSE.-SW. |
| Hakatatsu Maru, Jap. S. S. | Portland | Yokohama | 35 10 N. | 140 31 E. | 7 | 1 p., 8 | 8 | 29.20 | SSW | WSW., 1 | NW | WSW., 11 | |
| Makiki, Am. S. S. | San Francisco | Honolulu | 37 45 N. | 123 55 W. | 7 | 4 a., 7 | 9 | 29.94 | NW | NW., 9 | N | NW., 9 | NW.-N. |
| West Prospect, Am. S. S. | Hongkong | San Francisco | 35 20 N. | 147 50 E. | 7 | 4 p., 8 | 9 | 29.08 | S | S., 12 | W | S., 12 | S.-SW. |
| Rakuyo Maru, Jap. S. S. | Honolulu | Yokohama | 34 05 N. | 140 44 E. | 7 | 2 p., 8 | 9 | 29.13 | SSE | W., 10 | W | W., 11 | S.-W. |
| Makaweli, Am. S. S. | Ahukini | San Francisco | 35 45 N. | 129 30 W. | 8 | 12 p., 8 | 9 | 30.28 | N | N., 10 | N | N., 10 | Steady. |
| Radnor, Am. S. S. | Honolulu | Kobe | 32 30 N. | 140 30 E. | 8 | | 9 | 29.41 | W | W., 10 | NW | W., 12 | Do. |
| Yankee Arrow, Am. S. S. | Nagasaki | Los Angeles | 36 03 N. | 149 49 E. | 7 | 5 p., 8 | 10 | 29.15 | S | S., 12 | W | S., 12 | S-WSW. |
| Las Vegas, Am. S. S. | Otaru | San Pedro | 42 45 N. | 156 00 E. | 7 | 5 a., 9 | 10 | 28.73 | ESE | SSE., 10 | WSW | SSE., 11 | SSE.-WSW. |
| Dickenson, Am. S. S. | Honolulu | Midway Island. | 23 50 N. | 170 42 W. | 8 | 3 a., 8 | 10 | 29.92 | WSW | WSW., — | NE | NW., 8 | NW. |
| Steel Age, Am. S. S. | Formosa | Port Townsend. | 35 55 N. | 143 04 E. | 7 | 2 a., 11 | 11 | 29.57 | NW | NW., — | NNW | WSW., 10 | WSW.-NW. |
| Wheatland Montana Am. S. S. | Vancouver | Yokohama | 48 18 N. | 169 20 E. | 9 | 11 p., 9 | 10 | 29.65 | SSE | SE., 11 | SW | SE., 11 | SE.-SW. |
| Pres. Polk, Am. S. S. | Honolulu | Kobe | 32 56 N. | 150 35 E. | 8 | 7 p., 8 | 11 | 29.47 | SE | SE., 9 | W | SE., 10 | SE.-SW. |
| Africa Maru, Jap. S. S. | Victoria | Yokohama | 42 27 N. | 170 13 E. | 12 | Noon, 14 | 14 | 29.18 | E | E., — | WSW | WSW., 10 | E.-WSW. |
| Protesilaus, Br. S. S. | Yokohama | Victoria | 47 21 N. | 171 06 E. | 13 | 4 a., 14 | 14 | 28.66 | ENE | ESE., 10 | SW | ESE., 11 | E.-SE. |
| Canadian Freighter, Br. S. S. | Chemainus | Balboa | 47 20 N. | 125 05 W. | 14 | 11 p., 14 | 15 | 29.71 | ESE | SE., 9 | SE | SE., 9 | ESE.-SE. |
| Protesilaus, Br. S. S. | Yokohama | Victoria | 50 10 N. | 159 30 W. | 16 | 4 a., 16 | 18 | 29.26 | SSE | S., 9 | SW | SW., 10 | ESE.-SW. |
| Shabonee, Br. S. S. | San Pedro | Nagasaki | 30 20 N. | 140 24 E. | 18 | 1 p., 18 | 19 | 29.87 | WNW | WNW., 8 | NNW | NW., 9 | WNW.-NW. |
| India Arrow, Am. S. S. | Foochow | San Francisco | 38 33 N. | 168 05 E. | 18 | 11 p., 19 | 19 | 29.14 | S | SSW., 10 | W | SSW., 10 | S.-SSW.-W. |
| Kurohime Maru, Jap. S. S. | Yokohama | do | 45 02 N. | 164 00 E. | 18 | 4 p., 20 | 21 | 28.45 | E | WNW., 1 | W | E., 11 | WNW.-NW. |
| Do | do | do | 47 13 N. | 174 55 E. | 22 | 6 p., 22 | 23 | 28.98 | | SW., — | WSW | WSW., 11 | SW.-WSW. |
| Stockton, Am. S. S. | Cebu | Portland | 45 00 N. | 139 00 W. | 19 | 6 p., 20 | 21 | 29.94 | W | NW., 10 | NW | NW., 10 | Steady. |
| Pres. Grant, Am. S. S. | Seattle | Yokohama | 49 19 N. | 172 23 E. | 20 | 4 a., 20 | 23 | 28.75 | E | E., 7 | NNW | E., 10 | E.-ESE. |
| West Ison, Am. S. S. | Orient | Seattle | 29 55 N. | 133 50 E. | 21 | 2 a., 21 | 24 | 29.40 | ESE | ESE., 7 | NW | W., 11 | W.-N.-NNW. |
| Elkton, Am. S. S. | Manila | Shanghai | 16 50 N. | 119 40 E. | 22 | 4 a., 22 | 25 | 29.80 | NNE | N., — | NE | NE., 10 | NNE.-N. |
| Steel Age, Am. S. S. | Formosa | Port Townsend. | 48 50 N. | 128 00 W. | 23 | 4 p., 28 | 28 | 29.27 | W | SSE., 11 | W | SSE., 11 | SSE.-SW. |
| West Niger, Am. S. S. | Yokohama | Portland | 45 25 N. | 179 54 E. | 23 | —, 24 | 27 | 29.14 | SE | SE., 8 | WSW | S., 10 | S.-SW. |
| India Arrow, Am. S. S. | Foochow | San Pedro | 38 10 N. | 140 40 W. | 28 | 8 a., 29 | 29 | 29.22 | SSW | S., 10 | SW | S., 10 | S.-SW. |
| Sunugentco, Am. S. S. | Newark, N. J. | do | 14 15 N. | 94 52 W. | 29 | 5 a., 29 | 29 | 29.84 | N | NNE., 8 | NNW | NE., 9 | N.-NE. |
| Pacific, Am. S. S. | Everett | Los Angeles | 44 00 N. | 124 38 W. | 28 | 8 p., 28 | 31 | 29.78 | S | SE., 10 | S | SE., 12 | S.-SE. |
| Lebec, Am. S. S. | San Pedro | Cordova | 50 27 N. | 134 03 W. | 28 | 3 a., 30 | 31 | 28.97 | SSW | SSE., 8 | SSW | SSE., 10 | SSE.-S. |
| West Ison, Am. S. S. | Orient | Seattle | 47 20 N. | 174 05 E. | 30 | 4 p., 30 | 31 | 29.26 | ENE- | ENE., 8 | NNW | ENE., 9 | ENE.-N.-NW |

## NORTH PACIFIC OCEAN

By WILLIS E. HURD

December, 1926, was one of the stormiest months in recent years on the North Pacific Ocean. Gales of force 9 or over were of daily occurrence. Storm winds were reported on at least 10 days, and hurricane velocities are known to have been experienced by vessels on 6 days. Very sharp gradients and rapid fluctuations in the Aleutian LOW caused more gales than usual along the eastern half of the northern steamer routes, and several hard Asiatic storms swept with unwonted fierceness the waters between Japan and the 180th meridian.

Among the storms of the Far East, that of the 7th to 11th was the most notable, and was the worst of December for any part of the ocean. It entered the Yellow Sea from China as a shallow depression on the 6th, closely followed by an anticyclone of great magnitude from Siberia. It deepened rapidly on the 7th and 8th, during which time it traversed Japan from south to north, causing southerly to westerly gales and snows over a great part of the archipelago and neighboring waters. Whole gales to hurricane winds occurred intermittently on the 8th and 9th over a considerable part of the area from 30° N., 135° E., northeastward to 50° N., 170° E., while in scattered localities within or near this region forces up to 11 were encountered on the 6th and 7th, and up to 10 on the 10th and 11th. On the 8th the pressure gradients along the 32d parallel were very steep, the barometer readings ranging between 30.80 inches over China in 116° E., and 29.20 inches, in 137° E.

Two subsequent storms of this region were those of the 14th to 19th and the 20th to 24th, both of which caused strong gales over the western Pacific north of the 25th parallel, between the 135th and 170th meridians of east longitude. On the 18th and 22d winds of storm force occurred near southeastern Japan, and on the 19th, near 45° N., 165° E.

In consequence of the pronounced anticyclonic activities over southeastern Asia, a strong northeast monsoon prevailed along the coast, rising in force to 10 over the northeastern part of the China Sea on the 23d and 24th.

High winds occurred in the neighborhood of Midway Island on the 1st, 6th, 7th, and 8th—reaching the force of a storm on the 7th—in conjunction with the far-reaching fluctuations of the Aleutian LOW, then near or to the southward of Dutch Harbor.

This LOW showed much activity during December, reinforced considerably as it was by the entrance of the Asiatic cyclones previously mentioned. It oscillated considerably from day to day between the middle Aleutians and the eastern part of the Gulf of Alaska, but its average center was near Kodiak, where the monthly pressure was 29.33 inches, a quarter of an inch below the normal. At Dutch Harbor pressure was low except from the 8th to 12th, at which time a remarkable increase occurred. Here the minimum reading of the month, 28.56 inches, on the 7th, was followed on the 10th by the unusually high maximum of 30.72 inches, thus accomplishing in three days a pressure change of more than two inches. Frequent high winds in northern and middle latitudes attended the movements of the LOW, although the severest gales, those reaching force 11, were localized near 48° N., 162° W., on the 2d and 6th. Offshoots of the main disturbance entered the American mainland on ten days. At the end of the month the LOW had spread well over the eastern part of the ocean north of the 35th parallel, causing stiff gales off the Washington and Oregon coasts and to the northward. On the 28th a force of 11 was encountered by the *Steel Age* off Vancouver Island, and a southerly gale with a maximum velocity of 66 miles per hour was registered by the Weather Bureau Station at Tatoosh Island. On the 29th the American steamer *Pacific* reported a hurricane wind off the upper Oregon coast. These occurrences were followed by lesser gales in the same locality until early in January.

The North Pacific permanent HIGH, normally central in December near 32° N., 138° W., covered very nearly its usual position—though with considerable daily changes—except on the first and last few days of the month, when its place was largely occupied by the Aleutian LOW.

The following table of pressure data gives further indication of barometric conditions east of the 180th meridian:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressures at sea level at indicated hours, North Pacific Ocean, December, 1926*

| Station | Average pressure | Departure from normal | Highest | Date | Lowest | Date |
|---|---|---|---|---|---|---|
| | *Inches* | *Inch* | *Inches* | | *Inches* | |
| Dutch Harbor [1] | [3] 29.41 | −0.17 | 30.72 | 10th | 28.56 | 7th. |
| St. Paul [1] | [3] 29.56 | −0.05 | 30.76 | 10th [5] | 28.90 | 26th. |
| Kodiak [1] | [3] 29.33 | −0.25 | 30.44 | 11th | 28.66 | 30th. |
| Midway Island [1] | [3] 30.02 | −0.02 | 30.28 | 28th | 29.58 | 5th. |
| Honolulu [2] | 30.01 | 0.00 | 30.19 | 27th | 29.85 | 14th. |
| Juneau [2] | 29.66 | −0.13 | 30.54 | 12th | 28.86 | 30th. |
| Tatoosh Island [2 4] | 30.01 | +0.04 | 30.57 | 8th | 29.26 | 1st. |
| San Francisco [2 4] | 30.10 | −0.01 | 30.49 | 27th | 29.73 | 2d. |
| San Diego [2 4] | 30.02 | −0.02 | 30.45 | 28th | 29.66 | 4th. |

[1] P. m. observations only.
[2] A. m. and p. m. observations.
[3] 30 days.
[4] Corrected to 24-hour mean.
[5] And other date.

At Honolulu pressure was normal, but the average temperature, 75°, was next to the highest on record for the month. The prevailing wind direction was east, and the maximum velocity, 34 miles from the east, on the 25th. The average hourly velocity at the station was 7.4 miles, but for the 24th to 28th, inclusive, was 16.5 miles. The total precipitation was 1.93 inches, which is 2.03 inches below the normal. Precipitation was slightly below normal, also, along much of the American coast, except southern California and to the northward of Washington. At Juneau the total of 14.43 inches exceeded by 1.10 inches the previous December record. Here 31.3 inches of snow fell.

Fewer gales than usual occurred off the tropical American coast. Northers of force 8 to 9 were reported by vessels in or south of the Gulf of Tehuantepec on the 29th and 31st.

The December occurrence of fog varied considerably from that of the previous November. A marked decrease was noticed along the American coast, where it was reported on only three days this month. In east longitudes fog was reported on the 27th only, whereas it was noted on six days in November. However, fog increased perceptibly in the region between 32° and 52° N., 130° and 170° W., where the phenomenon was noted scatteringly on 15 days.

# DETAILS OF THE WEATHER IN THE UNITED STATES

## GENERAL CONDITIONS

On the whole the month was close to a normal December. Pressure was relatively high in northern districts from the Atlantic to the Pacific and relatively low in the southern third of the country. Temperature was above normal in that section and also in the Pacific Coast States; it was quite generally less than normal from the middle and northern Plateau region eastward to the Atlantic. (See Chart III.) Precipitation was greater than the normal rather generally in the Rocky Mountain States and from Texas northeastward to the Virginias. Droughty conditions prevailed in the Southeastern States, the Lake region, portions of the middle Mississippi Valley, and the Pacific Coast States. (See the inset on Chart IV.)—*A. J. H.*

## CYCLONES AND ANTICYCLONES

By W. P. DAY

Twenty-three low-pressure areas were traced in their migrations within the limits of the weather chart during the month of December. This number is rather more than the normal, and these warm-air masses were quite varied with respect to place of origin. The surface pressure gradients, however, were sufficient in only a few cases to cause stormy weather. Only 14 cold-air masses of HIGHS were plotted, and the only important temperature depression occurred during the middle of the month, when a cold-air mass spread slowly southeastward from the Canadian interior and Alaska.

## FREE-AIR SUMMARY

By L. T. SAMUELS

An inspection of Table 1 shows negative temperature departures in the lower levels at all stations, with a change to positive in the higher levels at Ellendale, Groesbeck, and Royal Center. Relative humidity departures were small, and those of vapor pressure followed closely those of temperature.

The futility of assuming that the generally accepted average lapse rate of 0.6° C. per 100 m. is even approximately constant irrespective of location or season is clearly brought out in this table. It will be observed that at Ellendale, the northernmost station, the mean temperature at 3,000 m. was practically no lower than the mean at the surface. Although the average lapse rates for this November at the other stations (particularly the eastern ones) were considerably greater than this, yet they were much less than 0.6° C. per 100 m.

From Table 2 it will be seen that the resultant wind movement for the month was close to normal at the aerological stations. This is especially well shown for the country by pilot-balloon observations from 32 well-distributed stations. These show for the 3,000 m. (m. s. l.) level a practically due west direction over the country with the exception of the most northern and Pacific Coast States, where the resultant direction was northwest. It is interesting to note that the highest resultant velocities occurred not at the most northern stations, but over the middle latitudes of the country reaching a maximum at the eastern stations. This is the normal latitudinal relationship both for resultant and average wind velocities when the latter are considered without respect to direction. (See MONTHLY WEATHER REVIEW SUPPLEMENT, No. 26, 1926.)

A kite flight reaching to 4,000 m. made at Due West on the morning of the 27th is of special interest in connection with the occurrence of precipitation over that region considerably earlier than the prevailing sea-level pressure distribution indicated. (See a. m. weather map, December 27). This record was obtained in the southwest quadrant of an extensive anticyclone about midway between its center and periphery. With no precipitation occurring east of Texas at the time and with the entire eastern half of the country under the control of high pressure, it was unusual to find intermittent rains occurring as far east as Due West, where a steady rain set in by midnight and continued throughout the following day. The outstanding feature shown by this record was a cold east-northeasterly surface wind overrun by a very warm one from the south. Accordingly, at 2,100 m., the temperature was 7.2° C., while at the surface it was 1.6° C. and the average lapse rate from 2,100 m. to 4,000 m., 0.45° C. per 100 m.

At the beginning of the flight only high A-St. and Ci clouds moving from the west were present. Before the highest altitude was reached, however, these clouds became obscured by lower St. Cu. moving from south-southeast. Some lower St. moving from the east also appeared. It is of particular interest to find that the already pronounced temperature inversion referred to above became even more marked by the following morning (28th) when a kite flight which was made during rain showed the temperature at 1,250 m. to have increased 10° C. although the surface temperature remained about the same as on the previous day. It is probable that an even higher temperature prevailed above this level, but the altitude of the kites was limited when they became waterlogged and were beaten down by the strong winds (23 m. p. s. from the southwest).

Two explanations of this rain might be advanced—first, the forced ascent of the warm, moist southerly air, and second, the overrunning of the very warm air (as shown by the observation of the 28th) by relatively colder air above.

The chief significance here lies in the fact that pilot-balloon observations were impracticable throughout this whole region on account of the low clouds and precipitation, and therefore kite observations provided the only source of information regarding the upper air. The subsequent increase in this storm's intensity and its very rapid movement northeastward during the following 24 hours are intimately connected with the conditions shown by these kite records. That of the 28th is of particular interest in that it showed a state of saturation throughout this very pronounced inversion layer, a condition not frequently observed.

During another period of low clouds and intermittent rains at Groesbeck on the 20th when ordinarily both kite and pilot-balloon observations would be impracticable a valuable pilot-balloon observation was secured owing to the alertness on the part of the personnel during a temporary break in the lower clouds. With reference thereto the official in charge reports:

> As it was evident that this condition would not last long, the time of the balloon ascension was advanced to 1.21 p. m., thus obtaining an altitude (3,000 m.) that could not have been reached at any other time that day. This observation is of special interest in connection with the rapidly moving LOW attended by heavy rains which crossed the Southern States on the 19th, 20th and 21st.

At the time of this observation Groesbeck appeared to be on the dividing line between a LOW centered over Mexico and a HIGH central over the Atlantic coast. The significant feature shown was a 27 m. p. s. wind from the southwest at and above 1,300 m. elevation, overrunning a light surface wind of 5 m. p. s. This observation is striking, since during the ensuing night this LOW moved rapidly northeastward, being centered over Arkansas the following morning.

On the 11th both the morning and afternoon pilot-balloon observations at Cheyenne indicated exceptionally strong winds at a low elevation. In the morning a maximum velocity of 55 m. p. s. from the northwest was recorded at 800 m. above the surface where the velocity was only 11 m. p. s., while in the afternoon a 53 m. p. s. wind from the west was recorded at 1,000 m. with 16 m. p. s. at the ground. The fact that these were single-theodolite observations introduces an element of uncertainty in accepting these high velocities. The close agreement found between the morning and afternoon observations, however, strongly substantiates their accuracy, as it does not seem probable that a strong downward component would continue for such a long period. A strong area of low pressure central over Saskatchewan provided favorable conditions for chinook winds, and while the sea-level pressure distribution did not indicate such extreme velocities they may have actually occurred over a limited area. Some double-theodolite observations in this mountain region are needed to check up the seemingly erratic velocities occasionally found here.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during December, 1926*

TEMPERATURE (°C.)

| Altitude (meters) m. s. l. | Broken Arrow, Okla. (233 meters) Mean | Broken Arrow Departure from 9-yr. mean | Due West, S. C. (217 meters) Mean | Due West Departure from 6-yr. mean | Ellendale, N. Dak. (444 meters) Mean | Ellendale Departure from 9-yr. mean | Groesbeck, Tex. (141 meters) Mean | Groesbeck Departure from 9-yr. mean | Royal Center, Ind. (225 meters) Mean | Royal Center Departure from 9-yr. mean | Washington, D. C.[1] (7 meters) (mean) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 2.6 | −1.9 | 8.1 | −0.6 | −10.9 | −2.1 | 8.3 | −1.0 | −2.7 | −0.9 | 0.6 |
| 250 | 2.5 | −2.0 | 8.0 | −0.7 | | | 8.2 | −0.9 | −2.9 | −1.0 | −0.6 |
| 500 | 2.1 | −1.9 | 7.5 | −0.9 | −10.8 | −2.1 | 8.1 | −0.5 | −4.7 | −1.5 | −1.7 |
| 750 | 2.0 | −1.9 | 7.5 | −0.7 | −9.1 | −1.3 | 8.1 | −0.3 | −5.6 | −1.9 | −1.7 |
| 1,000 | 2.1 | −2.3 | 7.3 | −0.5 | −7.3 | −0.6 | 9.3 | +0.7 | −5.3 | −1.6 | −1.7 |
| 1,250 | 3.1 | −1.5 | 6.9 | −0.3 | −6.7 | −0.6 | 9.3 | +1.0 | −4.1 | −0.5 | −1.8 |
| 1,500 | 3.1 | −1.2 | 6.0 | −0.3 | −6.2 | −0.1 | 9.3 | +1.5 | −4.3 | −0.6 | −2.0 |
| 2,000 | 2.0 | −0.9 | 4.6 | 0.0 | −6.9 | +0.3 | 7.4 | +1.2 | −4.8 | +0.2 | −2.7 |
| 2,500 | 0.1 | −0.7 | 2.6 | −0.1 | −8.6 | +0.7 | 5.3 | +1.2 | −6.8 | +0.1 | −4.0 |
| 3,000 | −2.0 | −0.4 | 0.6 | −0.1 | −10.7 | +1.1 | 3.2 | +1.4 | −9.1 | +0.1 | −6.3 |
| 3,500 | −4.0 | 0.0 | −2.0 | −0.4 | −13.5 | +1.1 | 0.6 | +1.4 | −11.1 | +0.8 | −9.0 |
| 4,000 | −7.1 | −0.2 | −5.0 | −0.4 | | | −2.4 | +1.1 | | | |

[1] Naval air station.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during December, 1926*—Continued

RELATIVE HUMIDITY (%)

| Altitude (meters) m. s. l. | Broken Arrow, Okla. (233 meters) Mean | Broken Arrow Departure from 9-yr. mean | Due West, S. C. (217 meters) Mean | Due West Departure from 6-yr. mean | Ellendale, N. Dak. (444 meters) Mean | Ellendale Departure from 9-yr. mean | Groesbeck, Tex. (141 meters) Mean | Groesbeck Departure from 9-yr. mean | Royal Center, Ind. (225 meters) Mean | Royal Center Departure from 9-yr. mean | Washington, D. C. (7 meters) (mean) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 73 | +2 | 70 | −3 | 82 | 0 | 79 | +5 | 80 | 0 | 63 |
| 250 | 73 | +2 | 69 | −3 | | | 76 | +4 | 80 | 0 | 63 |
| 500 | 68 | +3 | 65 | −1 | 81 | +1 | 71 | +3 | 84 | +6 | 62 |
| 750 | 63 | +3 | 62 | −1 | 71 | −2 | 68 | +4 | 83 | +9 | 60 |
| 1,000 | 56 | +3 | 58 | −3 | 64 | −2 | 60 | +2 | 75 | +8 | 59 |
| 1,250 | 43 | −3 | 55 | −4 | 60 | −1 | 56 | +2 | 67 | +6 | 57 |
| 1,500 | 37 | −5 | 50 | −7 | 57 | −1 | 49 | −1 | 66 | +8 | 55 |
| 2,000 | 31 | −6 | 45 | −8 | 52 | −3 | 45 | +2 | 56 | +2 | 55 |
| 2,500 | 31 | −5 | 47 | −2 | 50 | −5 | 42 | +3 | 53 | 0 | 56 |
| 3,000 | 31 | −5 | 49 | +7 | 49 | −5 | 41 | +5 | 49 | −4 | 52 |
| 3,500 | 31 | −5 | 48 | +6 | 47 | −6 | 39 | +6 | 44 | −10 | 46 |
| 4,000 | 29 | −6 | 47 | +5 | | | 58 | +24 | | | |

VAPOR PRESSURE (mb.)

| Altitude (meters) m. s. l. | Broken Arrow Mean | Broken Arrow Departure | Due West Mean | Due West Departure | Ellendale Mean | Ellendale Departure | Groesbeck Mean | Groesbeck Departure | Royal Center Mean | Royal Center Departure | Washington |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 5.78 | −0.67 | 8.20 | −0.66 | 2.43 | −0.39 | 9.45 | −0.20 | 4.43 | −0.18 | 4.38 |
| 250 | 5.75 | −0.65 | 8.09 | −0.67 | | | 9.06 | −0.24 | 4.34 | −0.21 | 4.03 |
| 500 | 5.35 | −0.36 | 7.42 | −0.63 | 2.39 | −0.38 | 8.50 | −0.02 | 3.90 | −0.01 | 3.71 |
| 750 | 4.93 | −0.23 | 7.11 | −0.42 | 2.40 | −0.22 | 8.09 | +0.30 | 3.66 | +0.07 | 3.73 |
| 1,000 | 4.34 | −0.25 | 6.40 | −0.54 | 2.41 | −0.10 | 7.68 | +0.74 | 3.32 | +0.09 | 3.76 |
| 1,250 | 3.31 | −0.69 | 5.95 | −0.46 | 2.35 | −0.05 | 7.00 | +0.82 | 3.16 | +0.23 | 3.63 |
| 1,500 | 2.83 | −0.76 | 5.06 | −0.74 | 2.39 | +0.12 | 5.91 | +0.53 | 3.01 | +0.31 | 3.42 |
| 2,000 | 2.09 | −0.76 | 4.01 | −0.70 | 2.10 | +0.16 | 4.84 | +0.84 | 2.45 | +0.18 | 3.10 |
| 2,500 | 1.69 | −0.67 | 3.51 | −0.30 | 1.75 | +0.12 | 4.22 | +1.12 | 1.90 | −0.04 | 2.73 |
| 3,000 | 1.40 | −0.60 | 3.29 | +0.32 | 1.46 | +0.16 | 3.93 | +1.46 | 1.62 | −0.06 | 1.82 |
| 3,500 | 1.29 | −0.46 | 2.81 | +0.22 | 0.99 | 0.00 | 3.57 | +1.70 | 1.42 | −0.05 | 0.80 |
| 4,000 | 1.12 | −0.39 | 2.38 | +0.32 | | | 4.57 | +2.87 | | | |

TABLE 2.—*Free-air resultant winds (m. p. s.) during December, 1926*

| Altitude (meters) m. s. l. | Broken Arrow, Okla. (233 meters) Mean Dir. | Mean Vel. | 9-year mean Dir. | 9-year mean Vel. | Due West, S. C. (217 meters) Mean Dir. | Mean Vel. | 6-year mean Dir. | 6-year mean Vel. | Ellendale, N. Dak. (444 meters) Mean Dir. | Mean Vel. | 9-year mean Dir. | 9-year mean Vel. | Groesbeck, Tex. (141 meters) Mean Dir. | Mean Vel. | 9-year mean Dir. | 9-year mean Vel. | Royal Center, Ind. (225 meters) Mean Dir. | Mean Vel. | 9-year mean Dir. | 9-year mean Vel. | Washington, D. C. (34 meters) Mean Dir. | Mean Vel. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | S. 75° W. | 0.6 | S. 56° W. | 1.1 | S. 72° W. | 1.3 | S. 69° W. | 1.4 | N. 81° W. | 3.3 | N. 54° W. | 3.4 | N. 17° W. | 1.6 | N. 67° W. | 1.1 | S. 69° W. | 2.3 | S. 56° W. | 2.4 | N. 29° W. | 1.0 |
| 250 | S. 72° W. | 0.6 | S. 51° W. | 1.3 | S. 70° W. | 1.5 | S. 63° W. | 1.6 | | | | | N. 28° W. | 1.0 | S. 86° W. | 1.3 | S. 69° W. | 2.5 | S. 54° W. | 2.6 | N. 44° W. | 3.0 |
| 500 | S. 38° W. | 1.4 | S. 48° W. | 3.0 | S. 69° W. | 4.3 | S. 66° W. | 3.6 | S. 89° W. | 4.0 | N. 60° W. | 3.8 | S. 62° W. | 1.0 | S. 62° W. | 2.5 | S. 68° W. | 5.1 | S. 60° W. | 5.5 | N. 55° W. | 6.0 |
| 750 | S. 54° W. | 2.2 | S. 53° W. | 3.9 | S. 70° W. | 6.9 | S. 70° W. | 5.3 | S. 89° W. | 7.1 | N. 59° W. | 5.9 | S. 74° W. | 1.9 | S. 60° W. | 3.6 | S. 75° W. | 7.2 | S. 69° W. | 7.2 | N. 58° W. | 7.5 |
| 1,000 | S. 64° W. | 2.8 | S. 67° W. | 4.5 | S. 81° W. | 8.3 | S. 77° W. | 6.8 | W. | 8.3 | N. 57° W. | 7.0 | S. 71° W. | 2.9 | S. 61° W. | 4.8 | S. 85° W. | 7.9 | S. 79° W. | 8.4 | N. 60° W. | 8.1 |
| 1,250 | S. 76° W. | 3.8 | S. 78° W. | 5.0 | S. 80° W. | 9.2 | S. 78° W. | 8.2 | N. 83° W. | 9.3 | N. 58° W. | 7.7 | S. 80° W. | 4.1 | S. 67° W. | 5.8 | W. | 8.8 | S. 83° W. | 10.1 | | |
| 1,500 | S. 78° W. | 5.5 | S. 81° W. | 5.9 | S. 82° W. | 11.7 | S. 84° W. | 9.6 | N. 78° W. | 8.8 | N. 57° W. | 8.5 | S. 85° W. | 5.3 | S. 70° W. | 6.7 | N. 85° W. | 10.7 | S. 89° W. | 11.0 | N. 73° W. | 10.3 |
| 2,000 | S. 82° W. | 7.5 | S. 83° W. | 7.4 | S. 82° W. | 16.8 | S. 85° W. | 11.4 | N. 77° W. | 11.2 | N. 50° W. | 10.2 | S. 81° W. | 7.4 | S. 74° W. | 8.0 | N. 85° W. | 12.6 | N. 88° W. | 12.7 | N. 71° W. | 11.1 |
| 2,500 | S. 78° W. | 9.0 | S. 86° W. | 9.4 | S. 85° W. | 16.2 | S. 88° W. | 11.8 | N. 74° W. | 12.7 | N. 61° W. | 11.9 | S. 82° W. | 10.3 | S. 77° W. | 9.6 | N. 85° W. | 16.1 | N. 86° W. | 14.5 | N. 69° W. | 14.9 |
| 3,000 | S. 77° W. | 9.7 | S. 89° W. | 10.6 | N. 83° W. | 16.0 | N. 86° W. | 13.5 | N. 72° W. | 12.6 | N. 64° W. | 13.2 | N. 76° W. | 10.9 | S. 78° W. | 11.2 | N. 89° W. | 14.8 | N. 89° W. | 14.7 | N. 72° W. | 17.3 |
| 3,500 | S. 84° W. | 12.0 | N. 89° W. | 12.0 | N. 67° W. | 16.3 | N. 85° W. | 14.2 | N. 74° W. | 15.3 | N. 70° W. | 14.8 | N. 69° W. | 13.8 | S. 79° W. | 11.6 | N. 77° W. | 17.2 | N. 85° W. | 13.9 | N. 59° W. | 18.0 |
| 4,000 | S. 77° W. | 12.7 | N. 84° W. | 11.9 | N. 56° W. | 17.7 | N. 77° W. | 12.9 | S. 38° W. | 15.2 | N. 71° W. | 13.5 | N. 71° W. | 14.6 | S. 82° W. | 11.5 | | | | | | |
| 4,500 | W. | 16.0 | N. 83° W. | 12.5 | N. 56° W. | 19.2 | N. 78° W. | 15.7 | | | | | | | | | | | | | | |

## FREE-AIR SUMMARY FOR THE YEAR 1926

By L. T. SAMUELS

It is evident from Table 1 that free-air temperatures for the year, particularly in the lower levels, were mostly below their normal values. A general diminution of the departures with increase in altitude occurred in most cases, while a change to positive is found in the higher levels at Broken Arrow, Due West, Groesbeck, and Washington. It should be noted that the temperature departures for the naval air station at Washington are based on the Mount Weather, Va., records covering a five-year period (1907–1912). These have been omitted, however, below the 1,500 m. level on account of the great difference in elevation between these two stations and also because the Mount Weather data are based on the means of the ascents and descents of kite flights, whereas the airplane data represent ascents only. Above 1,500 m., however, there is probably very little difference due to either of these causes.

The persistence of a marked latitudinal normal temperature gradient to a considerable height above the surface is shown for the mid-western section of the country by a comparison of the Ellendale and Groesbeck data. It will be seen that the difference in the normal annual surface temperature between these two stations is 12.4° C., whereas at an altitude of 5,000 m. it is still 10.3° C., showing a net decrease of only 2.1° C. at this great height.

It is of interest also to note the longitudinal effect on the temperature gradient in the free air as shown by the records of Broken Arrow and Due West, these stations being almost on the same parallel of latitude. It is found that the normal annual surface temperature at Due West is 1.4° C. higher than at Broken Arrow, with the differences decreasing until a reversal takes place above 1,000 m. altitude, where Due West becomes the colder. The proximity of the ocean in this case would seem to be the paramount factor.

As would be expected with general negative temperature departures, the relative humidity was mostly above normal. Vapor pressures were below normal in the lower levels at all stations, but mostly above normal in the higher levels. (See Table 1.)

All previous minimum free-air temperature records for the month of September were broken at a number of stations on the 25th and 26th. On these dates the stations were under the influence of a strong high-pressure area and absolute minimum temperatures prevailed from the surface to altitudes reaching 4,000 m. at Ellendale. Similarly previous low-temperature records (particularly for the higher levels) for the month of January were broken at Drexel, Broken Arrow, and Royal Center on the 21st and 22d when a strong anticyclone passed over these stations.

Maximum free-air temperature records for July were exceeded for various levels at Royal Center, Ellendale, and Due West on the 18th–20th. During this period extremely high surface temperatures prevailed throughout these sections.

One of the outstanding aerological achievements of the year was a two-theodolite pilot-balloon observation made at Broken Arrow, Okla., on July 3. A 6-inch balloon was followed with both theodolites for 122 minutes and a practically uniform rate of ascent (190 m. p. m.) obtained during the first 100 minutes, at the end of which time the height was 19 km. During the last 22 minutes, however, the rate of ascent decreased considerably (averaging only about 90 m. p. m.) and the maximum height reached was 21 km. This observation was made in the southwest quadrant of a weak low-pressure area central over northwestern Missouri. The latitudinal surface temperature gradient over the country was extremely weak and therefore winds were light and favorable for such a long observation. A westerly wind prevailed from the surface to 3,500 m., where an abrupt veering to southeasterly occurred, the direction remaining so to the highest altitude. The wind velocity up to this height averaged only about 4 m. p. s. The balloon was finally eclipsed by Ci Cu clouds.

An unusual record of an exceptionally deep column of rapidly ascending air was obtained at Ellendale, N. Dak., on August 12 when a breakaway kite carrying the meteorograph rose abruptly from an altitude of 1,750 m. to 4,900 m. above the ground. The rate of the rising air current was approximately 10.5 m. p. s. For a detailed account of this observation see Free-air summary, MONTHLY WEATHER REVIEW, August, 1926.

During the following months the resultant wind movement was generally greater than normal:

February, March, April (particularly at northern stations) and August (particularly at Due West).

A general excess of north component in the resultant wind movement prevailed during March, June (particularly at Ellendale), July, November (particularly at Broken Arrow, Ellendale, and Groesbeck) and an excess of southerly component during August (particularly at Due West and Ellendale), September (particularly at Broken Arrow and Ellendale), October (particularly at Due West), and November (particularly at Due West and Royal Center).

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during the year 1926*

TEMPERATURE (°C.)

| Altitude (m.) m. s. l. | Broken Arrow, Okla. (233 meters) | | Due West, S. C. (217 meters) | | Ellendale, N. Dak. (444 meters) | | Groesbeck, Tex. (141 meters) | | Royal Center, Ind. (225 meters) | | Washington, D. C.[1] [2] (7 meters) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Departure from 9-yr. mean | Mean | Departure from 6-yr. mean | Mean | Departure from 9-yr. mean | Mean | Departure from 9-yr. mean | Mean | Departure from 9-yr. mean | Mean | Departure from 5-yr. mean |
| Surface | 14.9 | −0.7 | 16.5 | −0.5 | 5.9 | +0.2 | 17.6 | −0.5 | 9.8 | −1.3 | 10.9 | ----- |
| 250 | 14.8 | −0.7 | 16.2 | −0.5 | ----- | ----- | 17.0 | −0.5 | 9.0 | −1.3 | 10.1 | ----- |
| 500 | 13.6 | −0.6 | 14.5 | −0.4 | 5.6 | 0.0 | 15.8 | −0.4 | 7.8 | −1.2 | 9.4 | ----- |
| 750 | 12.6 | −0.6 | 13.2 | −0.4 | 4.9 | −0.2 | 14.9 | −0.4 | 6.8 | −1.0 | 8.5 | ----- |
| 1,000 | 11.8 | −0.5 | 12.0 | −0.4 | 4.5 | −0.2 | 14.2 | −0.4 | 6.0 | −0.8 | 7.5 | ----- |
| 1,250 | 11.0 | −0.4 | 10.7 | −0.5 | 4.0 | −0.2 | 13.4 | −0.4 | 5.2 | −0.6 | 6.4 | ----- |
| 1,500 | 10.2 | −0.2 | 9.5 | −0.5 | 3.3 | −0.1 | 12.6 | −0.3 | 4.2 | −0.6 | 5.4 | −0.8 |
| 2,000 | 8.1 | 0.0 | 7.1 | −0.5 | 1.1 | −0.2 | 10.4 | −0.4 | 2.2 | −0.5 | 3.7 | −0.3 |
| 2,500 | 5.5 | +0.1 | 4.7 | −0.4 | −1.5 | −0.2 | 8.1 | −0.3 | −0.2 | −0.6 | 1.6 | −0.1 |
| 3,000 | 2.8 | +0.2 | 2.3 | −0.3 | −4.4 | −0.3 | 5.5 | −0.4 | −2.7 | −0.5 | −0.9 | +0.1 |
| 3,500 | 0.0 | +0.2 | −0.5 | −0.4 | −7.4 | −0.5 | 2.4 | −0.8 | −5.1 | −0.3 | −3.8 | +0.2 |
| 4,000 | −2.9 | +0.2 | −3.0 | −0.5 | −10.6 | −0.9 | −0.1 | −0.5 | −7.7 | −0.4 | −6.2 | +0.8 |
| 4,500 | −5.6 | +0.3 | −6.3 | −0.2 | −13.8 | −1.2 | −2.3 | 0.0 | −10.1 | −0.2 | −9.4 | +0.8 |
| 5,000 | −8.3 | +0.4 | −8.1 | +1.0 | −16.0 | −0.6 | −3.8 | +1.3 | ----- | ----- | −12.0 | +1.3 |

RELATIVE HUMIDITY (%)

| Altitude (m.) m. s. l. | Broken Arrow, Okla. | | Due West, S. C. | | Ellendale, N. Dak. | | Groesbeck, Tex. | | Royal Center, Ind. | | Washington, D. C. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 68 | 0 | 66 | +1 | 69 | −3 | 74 | +1 | 72 | +2 | 75 | ----- |
| 250 | 68 | 0 | 66 | +1 | ----- | ----- | 73 | +1 | 72 | +2 | 73 | ----- |
| 500 | 66 | +1 | 65 | +1 | 68 | −3 | 72 | +2 | 72 | +3 | 69 | ----- |
| 750 | 64 | +1 | 65 | +1 | 65 | −2 | 70 | +3 | 71 | +3 | 68 | ----- |
| 1,000 | 62 | +1 | 64 | 0 | 62 | −2 | 66 | +3 | 69 | +3 | 67 | ----- |
| 1,250 | 58 | −1 | 63 | 0 | 60 | −1 | 62 | +3 | 67 | +3 | 67 | ----- |
| 1,500 | 55 | −2 | 61 | −1 | 59 | −1 | 58 | +2 | 66 | +4 | 67 | ----- |
| 2,000 | 50 | −3 | 58 | −1 | 56 | −1 | 53 | +3 | 61 | +4 | 65 | ----- |
| 2,500 | 46 | −4 | 54 | −2 | 54 | −2 | 49 | +3 | 58 | +4 | 63 | ----- |
| 3,000 | 45 | −3 | 51 | −2 | 54 | −1 | 47 | +4 | 54 | +2 | 61 | ----- |
| 3,500 | 44 | −4 | 50 | −1 | 55 | +1 | 45 | +4 | 51 | +1 | 59 | ----- |
| 4,000 | 43 | −4 | 54 | +3 | 57 | +4 | 45 | +5 | 55 | +7 | 57 | ----- |
| 4,500 | 41 | −4 | 53 | +3 | 58 | +5 | 43 | +6 | 59 | +10 | 51 | ----- |
| 5,000 | 46 | 0 | 44 | −5 | 54 | +3 | 58 | +21 | ----- | ----- | 51 | ----- |

[1] Naval air station.
[2] Based on observations made at Mount Weather, Va., July 1, 1907–June 30, 1912.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during the year 1926*—Continued

VAPOR PRESSURE (*mb.*)

| Altitude (*m.*) m. s. l. | Broken Arrow, Okla. (233 meters) | | Due West, S. C. (217 meters) | | Ellendale, N. Dak. (444 meters) | | Groesbeck, Tex. (141 meters) | | Royal Center, Ind. (225 meters) | | Washington, D. C. (7 meters) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Departure from 9-yr. mean | Mean | Departure from 6-yr. mean | Mean | Departure from 9-yr. mean | Mean | Departure from 9-yr. mean | Mean | Departure from 9-yr. mean | Mean | Departure from 5-yr. mean |
| Surface | 13.42 | −0.29 | 13.84 | −0.07 | 7.65 | −0.47 | 16.54 | −0.18 | 10.50 | −0.33 | 12.16 | ------ |
| 250 | 13.32 | −0.28 | 13.63 | −0.06 | ------ | ------ | 15.92 | −0.17 | 10.38 | −0.29 | 11.24 | ------ |
| 500 | 12.10 | −0.03 | 12.24 | −0.02 | 7.41 | −0.50 | 14.54 | −0.05 | 9.28 | −0.09 | 10.13 | ------ |
| 750 | 11.00 | +0.07 | 11.25 | 0.00 | 6.63 | −0.43 | 13.20 | +0.09 | 8.56 | +0.15 | 9.30 | ------ |
| 1,000 | 10.06 | +0.12 | 10.39 | +0.02 | 6.12 | −0.31 | 11.80 | +0.21 | 7.92 | +0.25 | 8.50 | ------ |
| 1,250 | 8.99 | +0.01 | 9.45 | −0.01 | 5.59 | −0.26 | 10.27 | +0.02 | 7.28 | +0.34 | 7.84 | ------ |
| 1,500 | 8.00 | −0.04 | 8.45 | −0.08 | 5.10 | −0.20 | 8.88 | −0.25 | 6.59 | +0.38 | 7.25 | ------ |
| 2,000 | 6.27 | +0.01 | 6.73 | −0.08 | 4.22 | −0.11 | 6.97 | −0.16 | 5.29 | +0.41 | 6.14 | ------ |
| 2,500 | 4.88 | −0.01 | 5.23 | −0.16 | 3.49 | −0.05 | 5.60 | −0.10 | 4.16 | +0.45 | 4.98 | ------ |
| 3,000 | 3.96 | +0.11 | 4.26 | −0.01 | 2.86 | +0.02 | 4.54 | −0.05 | 3.28 | +0.42 | 3.89 | ------ |
| 3,500 | 3.22 | +0.14 | 3.48 | +0.05 | 2.38 | +0.10 | 3.63 | −0.09 | 2.64 | +0.45 | 2.90 | ------ |
| 4,000 | 2.70 | +0.29 | 3.03 | +0.21 | 1.87 | +0.03 | 3.25 | +0.19 | 2.44 | +0.81 | 2.08 | ------ |
| 4,500 | 2.27 | +0.40 | 2.32 | +0.01 | 1.40 | −0.10 | 2.63 | −0.04 | 2.40 | +1.08 | 1.42 | ------ |
| 5,000 | 1.91 | +0.38 | 1.26 | +0.71 | 0.74 | −0.57 | 2.70 | +0.28 | ------ | ------ | 1.02 | ------ |

## THE WEATHER ELEMENTS

By P. C. DAY, In Charge of Division

### PRESSURE AND WINDS

There were few conditions that marked the weather as distinctive from that of an average winter month, though changes were frequent and important, as may be expected in the first month of winter.

Important cyclones were notably absent during the first decade, although there were some local heavy rains on the 2d and 3d in northern California and portions of the far Northwest and in southwestern Arizona on the 4th and 5th and again on the 10th; in fact rain was almost of daily occurrence from the 4th to 14th over much of the State, and in the vicinity of Yuma the local fall was far above the normal for the month and nearly twice as much as in any previous December of record.

During about the same period as referred to above there was rather widely scattered precipitation in the southern Plains, and thence east and northeast, some heavy falls occurring in northern Texas and near-by areas on the 6th and 7th and in southern Texas on the 10th.

A cyclone with marked barometric depression moved into the upper Missouri Valley on the 11th and thence rapidly advanced southward to Colorado during the following 24 hours, attended by some of the lowest pressures ever observed during December in that region. This storm merged with another moving in the same direction somewhat farther east, and curved sharply to the northeast during the afternoon and night of the 12th and on the morning of the 13th was central over the upper Lakes, moving thence to northward of the St. Lawrence Valley during the following day. Despite the low pressures in the early life of this cyclone it was not attended by important precipitation except far south of its center, in Tennessee and near-by sections, where local heavy rains occurred on the 13th and again on the 14th.

No extensive cyclonic disturbances occurred during the latter part of the second decade, but on the 20th pressure was low over the Southwest, and by the morning of the 21st the center of a moderate cyclone was over Arkansas and heavy rains had fallen over large areas in that and near-by States. At Little Rock a total fall of nearly 6 inches occurred within 24 hours on the 20th and 21st, and amounts nearly as large were reported from points in near-by States. As this storm moved northeastward toward the Middle Atlantic States local heavy rains occurred during the 22d.

Another cyclone moving from the southern Plains northeastward to the Great Lakes on the 23d and 24th again brought local heavy rains over much of the area covered by that of a few days previous. This was quickly followed by still another low-pressure area that moved from southern Texas northeastward, again causing heavy precipitation over much of the area visited by previous storms, but including much of the country to the eastward, though here the precipitation was mainly not so heavy.

By the morning of the 28th cyclonic conditions had overspread the lower Mississippi Valley and local heavy rains were again falling in that region, extending during the following 24 hours to all districts east and northeast, heavy rains falling in the Atlantic States with more or less snow in the Lake region, upper Ohio Valley, and to the northeast.

Anticyclones dominated the weather in the Plateau and in northern and central districts. One of the most important of these entered the upper Missouri Valley on the morning of the 13th and, drifting slowly southeastward, favored cold and fair weather over most central and eastern districts until the end of the second decade.

An extensive anticyclone covered the far Northwest on the 23d and by the following morning was centrally located over the middle Plateau, whence it drifted south and east during the following few days, but lost intensity as it approached the Atlantic coast.

By the 27th an anticyclone had overspread the California coast and moving into the middle Plateau dominated the weather from the Rocky Mountains westward until the close of the month.

Except in a few instances barometric gradients were not unusual, and hence wind velocities were not high or extensive; only in local areas was there damaging wind.

The prevailing directions were marked by unusual differences at neighboring stations and no important areas had prevailing winds uniformly from a single direction. Details concerning damage by winds or other storms appear at the end of this section.

### TEMPERATURE

December again showed a tendency toward above-normal temperatures over the far western districts, as in practically all the preceding months, while in the Great Lakes region and to the eastward a tendency toward lower than normal temperatures, which has persisted since February, was again rather marked.

As a whole the month had frequent changes in temperature and numerous comparatively brief cold waves moved across the northern and central districts from the Rocky Mountains eastward; no unusual cold was experienced over extensive areas.

The first week was decidedly cold over northern districts from the Rocky Mountains eastward, but mainly warmer than normal in the South and far West, the week being unusually warm in the middle Rocky Mountain and Plateau regions. The second week continued decidedly warmer than normal in the Southeast and moderately so in the Southwest, but there was a change to moderate cold in the far Northwest, and it continued cold in northern and central districts eastward as far as the Great Plains, and in the extreme Northeast.

The third week was mainly colder than normal, due to an extensive anticyclone that moved into the upper Missouri Valley at the beginning attended by subzero temperatures, and gradually spread eastward and southward, the pressure continuing high over most of the country until near the end of the week, though there was some warming up as the week advanced, particularly over the far West. The week as a whole was colder than normal in practically the whole country, and freezing temperatures extended to all parts save Florida, a narrow strip along the Gulf coast, in extreme southern Texas, and over the lower elevations of Arizona and California.

The last decade had frequent and over some districts important changes in temperature, with the coldest weather of the month about the middle of the decade in the Southwest and at the end at points in Florida. It was distinctly colder than normal from the Rocky Mountains westward and mainly near normal or warmer to the eastward.

The warmest periods were about the 1st and 2d over most portions from the Rocky Mountains westward and along the North Atlantic coast, about the 10th to 14th along the northern boundary and in the Ohio Valley and Middle Gulf States, and in the early part of the last decade along the South Atlantic coast. At Fresno, Calif., the maximum temperature on the 1st, 79°, was the highest ever observed in December.

The lowest temperatures were observed from the 5th to 7th along the North Atlantic coast, about the 14th to 16th from the far Northwest southeastward to the Ohio Valley and Middle Gulf States, about the 24th to 27th in the Southwest, and over the Florida Peninsula on the 31st.

The lowest temperature reported was −49° in the mountains of Wyoming, while at Ludington, on the east shore of Lake Michigan, a minimum of −4° on the 18th was the lowest ever observed at that station in December.

### PRECIPITATION

As has been the case for a number of months past, precipitation for the country as a whole was materially above normal, due not so much to the area covered, since more than half the States showed deficiencies, but to the heavy falls over restricted areas.

From Arizona and Utah eastward precipitation was everywhere above normal, except over the Florida Peninsula and the near-by portions of the Gulf and South Atlantic States. In portions of this area, notably in southwestern Arizona, the monthly amounts were far above normal and greatly exceeded any previous December precipitation in more than 50 years. In portions of northeastern Texas and thence over northern Louisiana, eastern Oklahoma, most of Arkansas, much of Kentucky and Tennessee, and northern Mississippi and Alabama, the monthly precipitation exceeded the normal December fall by from 5 to 10 inches, and in numerous instances the monthly amounts were the greatest or nearly the greatest ever received in December. The average for Tennessee was more than 6 inches above normal, the greatest December average of record.

The large totals of precipitation over the areas last referred to were confined mainly to the third decade, in which rains were of almost daily occurrence except on the last two or three. Local 24-hour falls during this period were in excess of 6 inches, in some instances the greatest ever measured in December.

The precipitation was moderately deficient in the Pacific Coast States and generally from Missouri and Iowa northeastward over the Lake region and New England, and from southern Louisiana eastward to the South Atlantic coast. In Florida the average precipitation was less than 1 inch, the least for December in nearly 40 years of statewide observations.

Heavy rains during the latter part of the month over portions of the lower Mississippi Valley and the southern tributaries of the Ohio caused serious floods, full details of which appear elsewhere in this issue.

### SNOWFALL

All parts of the country had more or less snow except the low elevations of the far Southwest and along the Pacific coast, and from eastern Texas to the Carolinas and southeastern Virginia, where practically no snow fell.

Snow was unusually heavy in portions of central and western New York, and elsewhere from central Pennsylvania to New England, and over parts of the Great Lakes region the amounts ranged usually from 10 to 25 inches or more. Over the western slopes of the Appalachians from southern Virginia to Maryland and westward to the Great Plains and thence northward to the Canadian boundary the amounts ranged up to 5 or locally to even 10 inches. Farther south there were mainly only light falls, except in portions of northern Texas, where amounts up to 5 inches or more were reported.

About the normal amounts fell in the RockyMountain States and to the westward, except in the central and northern Sierra and over much of Nevada and near-by areas, where there was a general deficiency, particularly in Nevada.

A near blizzard, but covering an unusually small area, visited Buffalo, N. Y., and its immediate vicinity on the 16th. Fifteen inches of snow fell, the greatest amount in many years, and the high winds caused much drifting and seriously delayed traffic.

Glaze and ice storms were reported locally in Iowa and at points eastward through Illinois, Indiana, and into Michigan on the 7th and in the vicinity of Harrisburg, Pa., on the 25th and 26th, where considerable damage was reported.

### RELATIVE HUMIDITY

Over practically all the country the average percentages of relative humidity were above normal, the principal exceptions being California and Oregon and the extreme Southeastern States, where the averages were mainly less than normal. Over portions of the Southwest the averages were at many points 10 to 15 per cent above normal, but elsewhere they were mainly near the normal.

## SEVERE LOCAL HAIL AND WIND STORMS, DECEMBER, 1926

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

| Place | Date | Time | Width of path, yards | Loss of life | Value of property destroyed | Character of storm | Remarks | Authority |
|---|---|---|---|---|---|---|---|---|
| Washington (western part of). | 1 | | | | | Severe wind | Thousands of dollars damage to plate-glass windows and roofs; telegraph, telephone, and transmission wires also damaged to some extent. | Times (Seattle, Wash.); official, U. S. Weather Bureau. |
| Eastport, Me., and vicinity. | 5-6 | | | | | Wind and snow | Traffic impeded | Official, U. S. Weather Bureau. |
| Iowa (northern part of) | 7 | | | | | do. | Railway traffic interrupted, and highways blocked by drifts. | Do. |
| California (southern part of) | 8-9 | | | | | Wind and rain | A considerable amount of citrus fruits whipped from trees in some sections; trees injured by twisting and breaking of limbs; barge sunk by sudden squall in San Pablo Bay. | Do. |
| Devils Lake, N. Dak., and vicinity. | 9-10 | | | | | Wind and snow | All highways blocked to motor traffic by drifts | Do. |
| Iowa (northern part of) | 13 | | | | | do. | Rail traffic delayed; highways obstructed | Do. |
| Buffalo, N. Y | 16 | | | 1 | | Gale and snow | Traffic considerably delayed; one death due to exposure. | Do. |
| Iowa (northern part of) | 23 | | | | | Wind and snow | Railway traffic delayed; roads blocked | Do. |
| Havre, Mont | 24 | | | | | Wind | Insecure signs, awnings, and chimneys blown down. | Do. |

## STORMS AND WEATHER WARNINGS

### WASHINGTON FORECAST DISTRICT

On December 5 storm warnings were ordered from Delaware Breakwater to Eastport, Me., for strong east winds accompanied by snow, which occurred as indicated. Warnings were changed to northwest the following day.

Storm warnings were ordered displayed the night of the 13th from Wilmington, N. C., to Eastport, in connection with a disturbance of marked intensity over Ontario. Warnings were ordered down south of Delaware Breakwater on the morning of the 14th and winds did not exceed fresh to strong north of Delaware Breakwater.

Small craft warnings were issued the morning of the 15th between Hatteras and Sandy Hook.

On the evening of the 25th, warnings were ordered from Delaware Breakwater to Eastport in connection with a disturbance over Kentucky, and strong winds and gales occurred as indicated.

Storm signals were ordered on the morning of the 28th from Norfolk to Eastport in connection with a disturbance over Mississippi of increasing intensity. This disturbance moved northeastward attended by strong winds and gales over the region indicated in the advices. Small-craft warnings were displayed on the east Gulf coast on the 28th.

Frost or freezing temperature warnings were issued for portions of the east Gulf and south Atlantic States on the 1st, 12th, 13th, 14th, 15th, 16th, 17th, 24th, 29th, and 30th.

Cold-wave warnings were ordered for limited areas several times during the month, but the changes were moderate in all cases and on two occasions delayed. No important cold waves occurred.—*R. H. Weightman.*

### CHICAGO FORECAST DISTRICT

December, 1926, in the Chicago forecast district was colder than usual, especially in the northern quarter, where the mean temperature ranged from about 4 to 8 degrees below normal. As to precipitation, less than the normal amounts occurred, as a rule, but the number of days with a trace or more of precipitation was comparatively large.

*Storms on the Great Lakes.*—The storm warning season continued until the termination of the 15th. During this period several disturbances affected the Great Lakes, but none was of much severity. However, either small craft or storm warnings were issued for all but one of these disturbances. The exception was the disturbance of the 7th–8th, which exhibited only minor force as it crossed the Lakes. The most important storm of the month was that of the 11th–14th. This was a deep disturbance from the northwest and it preceded a severe cold wave. Strong winds or gales occurred over most of the Great Lakes region in this connection. The warnings issued were general in scope and proved timely.

After the close of the storm-warning season, advisory warnings were issued on three occasions for interests on Lake Michigan, where navigation proceeds throughout the year as a rule.

The abnormally cold weather that prevailed at the beginning of the month resulted in a great accumulation of ice in the canals and locks at the "Soo," with the result that one of the earliest and greatest blockades ever experienced in the marine history of the Great Lakes existed for a few days at that time. More than 100 vessels of various kinds were held in the ice.

*Cold waves.*—Cold-wave warnings were issued for some part of the district on 11 dates, although in a few cases the warnings of one date were merely repetitions of those of the previous date. The most severe and widespread cold wave of the month covered the 12th–14th. It swept virtually the entire district. In some instances the 24-hour fall in temperature equaled or slightly exceeded 50 degrees. A second general and marked fall in temperature crossed the district from the 23d to the 25th, but in some areas the minimum temperature required to constitute a cold wave was not reached. Cold waves without warnings occurred in a number of instances, but over limited areas as a rule. In most of these cases the cold wave was of the "radiation" type. That is to say, the fall in temperature occurred over a snow-covered surface in or near the center of a high pressure area.

*Livestock warnings.*—Advices for the benefit of livestock interests were disseminated on the 12th for South Dakota, Nebraska, and Kansas, and on the 22d, for the Dakotas and western Nebraska.—*C. A. Donnel.*

### NEW ORLEANS FORECAST DISTRICT

Storms were not intense and only one cold wave required general warnings.

Northwest storm warnings were issued for the Texas coast in the morning of the 24th and verifying velocities

occurred on the east coast of Texas during the night of the 24th–25th.

On account of the customary early morning departure of fishermen from Corpus Christi, night advices for the benefit of small craft have been inaugurated for that locality and on the 12th and 23d advices based on the p. m. weather charts for "northers" beginning the following day were sent to Corpus Christi. Small craft warnings were displayed on the Texas coast on the 13th and on the Louisiana coast on the 28th.

Cold-wave warnings were issued for Oklahoma and northern Arkansas on the 3d but failed of verification because of the eastward movement of the large area of high pressure central over Saskatchewan Province in the morning of the 3d.

On the 12th a large area of low pressure, in the form of a crescent trough, was being forced rapidly southeastward in advance of a large area of high pressure over western Canada and northwestern United States. Cold-wave warnings were issued for the northwestern half of the district in the morning of the 12th and extended to the Texas coast at night and to the Louisiana coast the next morning.

The cold wave occurred as forecast except that in coast sections the fall in temperature was more gradual than it was elsewhere.

A moderate cold wave, for which timely warnings were issued, overspread the northern portion of the district on the 24th–25th.

Livestock warnings were issued for all severe conditions, mainly in connection with the cold-wave warnings.

Frost or freezing warnings for the coast sections were issued on the 13th, 14th, 15th, 16th, 24th, 25th, 28th, 29th, 30th, and 31st, and conditions generally occurred as forecast.

Fire-weather warnings for winds and weather increasing the fire hazard were issued for forested areas in Oklahoma on the 2d and 11th and in Arkansas on the 11th.

A warning of strong northerly winds reaching gale force at Tampico, Mexico, was issued on the 15th.—*R. A. Dyke.*

### DENVER FORECAST DISTRICT

The first half of the month was marked by great barometric activity and consequent unsettled weather conditions and decided temperature fluctuations. The outstanding feature was the almost unprecedented stormy weather that continued for a week or more in Arizona attending a LOW that entered California on the second of the month and remained over the southwest with varying intensity and in varying geographic positions until the morning of the 11th, when it finally disappeared, seemingly either filling up or drifting into old Mexico. This disturbance brought the heaviest December rains of record to southwestern Arizona, the total amount at Yuma, 4.43 inches, being nearly nine times the normal for December and one inch more than the normal amount for an entire year. A disturbance of great intensity appeared in northern Alberta on the evening of the 10th and took a course almost due south, reaching eastern Colorado by the morning of the 12th. This storm was succeeded by the rapid spread of high pressure, accompanied by severely cold weather, over the northwestern States. This HIGH continued over the northern part of the district until the 17th. Thereafter a series of disturbances moved eastward along the Canadian border, while several HIGHS entered and disappeared in the Plateau region until finally one formed that persisted during the closing days of December and well into January. These latter changes in pressure were attended by comparatively settled weather conditions during the latter half of the month.

Cold-wave warnings were issued the evening of the 11th for eastern Montana and northern Wyoming, and the morning of the 12th for southern Wyoming, eastern Colorado, and eastern New Mexico, livestock interests being notified in southern Wyoming and eastern Colorado. These warnings were timely and were fully justified except in New Mexico where the fall in temperature was too gradual for technical verification. On the 22d warning was issued for a moderate cold wave in eastern and southern Montana, eastern and southern Wyoming, and northeastern Colorado. While not fully verifying over the entire region specified, the temperature drop ranged from 16 to 24 degrees, with minimum readings from 16 degrees above to 4 degrees below zero. A warning the evening of the 25th of a moderate cold wave in northeastern Montana was fully verified in the extreme northeastern part of the State. Numerous advices of expected fresh to strong winds in southern Wyoming and eastern Colorado were issued for the benefit of the air mail services, most of them being well verified. Frequent frost or freezing temperature warnings were issued for southern Arizona, as were also the usual weekly advices of expected temperature conditions to the northwestern fruit shippers, supplemented by special advices in advance of the cold waves in Montana and Wyoming.—*E. B. Gittings, jr.*

### SAN FRANCISCO FORECAST DISTRICT

At the beginning of December the pressure was relatively low over all parts of the northeast Pacific Ocean, with a disturbance on the coast of Washington which required the continuance of storm warnings that had been ordered along the north coast on the last day of the previous month, and their extension to include all Puget Sound ports. Gales occurred along the coast during the afternoon of the 1st and on the Sound the following night, unusual velocities being recorded. At North Head the wind reached a velocity of 94 miles an hour and at Seattle 60 miles. Thereafter for several days the barometer rose over the ocean between our coast and Hawaii with the major axis of the HIGH lying in a general northeast-southwest direction. Several disturbances generated under this HIGH—that is to say, on its southeastern border, their direction of travel being governed by the main air currents along the periphery of the HIGH. The first formed off the northern California coast on the 2d, the next over the southern Plateau on the 6th, and the 3d over southern California on the 8th. Warnings were required on some part of the California coast for both the latter depressions, and northerly gales prevailed over the ocean on both dates, but were most severe on the 8th.

On the 10th a radical change in type took place, the major axis of the oceanic HIGH shifting to a northwest-southeast direction with a marked rise in pressure over high latitudes in midocean. This attitude of the Pacific HIGH, although modified at intervals, recurred presistently until the 26th of December, and the phenomena which attended it corroborated to a remarkable degree the views which had been entertained in the district forecast office regarding the connection between this lie of the isobars and concurrent pressure developments in the far Western States. In particular, it has been found that (1) when the major axis of the oceanic HIGH is as described, disturbances lodged in the air currents on the polar side of the HIGH travel in a south or southeastward direction,

or if they move eastward leave vigorous secondaries over the lower latitudes, and (2) that when the axis of the oceanic HIGH assumes the direction above described, if a Plateau HIGH exists at the same time it will disappear or be greatly vitiated in from 12 to 36 hours, no matter how intense it may appear to be. For instance, on the 10th the reduced pressure at Winnemucca was 30.52 inches. Twenty-four hours later a disturbance which had been centered near Cordova, Alaska, was over central Canada and the pressure at Winnemucca had fallen to 30.04 inches, while within another 24-hour period an independent LOW was located over Utah and rain had fallen in the Pacific Forecast District as far south as the Mexican border.

These incidents were, in a general way, repeated in the series of charts beginning on December 20th when, with a LOW centered over southeastern Alaska, a HIGH over Nevada rapidly disappeared, the pressure at Winnemucca falling from 30.24 inches on the date in question to 29.62 inches 24 hours later, and precipitation covering the Pacific States from the northern to the southern border within the same period. During the inclusive period mentioned, numerous storm warning displays were made on the north coast and occasionally over Puget Sound, namely, on the 10th, when warnings were ordered for the Washington coast, on the 14th for all points in Oregon and Washington, on the 17th for the northern California coast and on the 20th and 23d for all Washington and Oregon stations. In all cases the warnings were justified by subsequent winds in some part of the area specified, except in the case of those on the 14th which were attended by an anomalous absence of gale phenomena, considering the fact that pressure developments took place about as expected.

On the 26th a reversion to the southwest-northeast type of isobar occurred in the oceanic HIGH, which was immediately followed by the accumulation of high pressure over the Plateau and Rocky Mountain region and which persisted until the close of the month. Gale warnings were displayed on the 26th, 27th, 29th, 30th, and 31st for northern ports, all of which were followed by stong winds or gales in some part of the area affected.

The storm referred to as moving southeastward from Alaska on the 10th was followed by a southeastward movement of a great body of high pressure from polar regions which reached the North Pacific States on the 13th, requiring cold-wave warnings for eastern Washington and northern Idaho on the 12th. Advices of the approach of a general cold period were also sent to other parts of the forecast district which it was known would be affected, and the public was adequately forewarned.

Frequent frosts characterized the month in California and general warnings were issued for all or parts of that State on 19 dates. The most noteworthy were those which were followed by more or less general firing in the citrus districts on the 25th, 27th, 28th, and 29th.—*T. R. Reed.*

## RIVERS AND FLOODS

By H. C. FRANKENFIELD

The outstanding features of river regime during the month were the general and disastrous floods in the Southern streams tributary to the Ohio River, an unprecedented occurrence within the last 54 years. Only twice within this period (the floods of 1926 excluded), has the flood stage in the Upper Tennessee River been exceeded by a significant amount (39.5 feet at Chattanooga, Tenn., on December 31, 1901, and 34.4 feet on December 21, 1915). The lower Tennessee and the Cumberland Rivers have been entirely free from floods of consequence.

*Cumberland River.*—A period of moderate to heavy rains from December 8 to 13 was attended by marked rises in the rivers, and before the usual decline could be accomplished, another period of excessive rains came on (December 20 and 21), and a second and much more rapid rise set in. Over the drainage area of the Cumberland River, the average rainfall was a little over 4.25 inches, and flood warnings were indicated at once. Thus far creast stages only a few feet above the flood stages were indicated; in other words, moderately high floods only. Unfortunately, on December 24, another two-day heavy rain period began (average about 3.50 inches), and, as a matter of course, the flood conditions became greatly intensified. On December 25 additional warnings were issued for further rises of about 8 feet in a river already above flood stage. These second warnings were closely verified as to stage and time, and would have marked the crests of the flood had not another rain of about 1.50 inches fallen on December 27 and 28. Again more water was indicated and again warnings were revised to meet a situation that was already most grave, dangerous, and destructive. Not more than a foot or two of additional rise could occur above Nashville, but at and below that city a further increase of 3 or 4 feet was inevitable.

The table at the end of this report shows the crest stages reached. As a whole, the flood will rank in importance with that of January, 1882. The flood of 1926 was greater between Carthage and Nashville, Tenn., and may finally be determined to be greater in its entirety. This will be determined by a resurvey of several high-water marks of 1882.

Flood damage was most serious between Carthage and Nashville, and reliable estimates of its extent were unobtainable. Many persons, of the opinion that a repetition of the flood of 1882 was impossible, and especially at this time of the year, had done considerable building and had stored valuable property within the range of the flood waters to such an extent that it could not be moved within a reasonable time. Moreover, it was reported that much loss was due to the fact that many persons failed to heed the warnings for abnormally high water. It must be admitted also that considerable loss was occasioned through the fact that the earlier forecasts were not sufficiently broad. This can hardly be termed a failure of commission, as the coming of additional heavy rains added complications that could not be foreseen at the time the forecasts were made.

Two lives were lost during the flood, both in Nashville. Very incomplete reports of loss and damage are as follows:

| | |
|---|---|
| (1) Tangible property | $454, 342 |
| (2) Crops | 441, 300 |
| (3) Livestock | 68, 300 |
| (4) Suspension of business, etc | 113, 135 |
| Total | 1, 077, 077 |

Other estimates exceeded this total, the Nashville Banner estimating the losses in Nashville and vicinity alone at $1,500,000. The reported value of property saved through the warnings of the Weather Bureau was $1,207,850.

Newspaper reports indicate that at least 5,000 people in Nashville and 4,000 in other places were forced to abandon their homes. Much of the city of Nashville, especially East Nashville was under water, and at one

point the river was said to have been three miles in width.

*Tennessee River.*—The flood began about December 25, and the crest had just about reached Florence, Ala., at the end of the month. A complete account of this flood will appear in the Monthly Weather Review for January, 1927. A report of the Green River flood will also appear at that time.

*Kentucky River.*—These floods also owe their origin to the heavy rains of December 20–21 and were also augmented by the later rains. Warnings were issued on December 21, and again on December 22 and 25, but the later warnings failed of distribution over the mountainous sections of the upper river on account of complete interruption of communication, a fact that also prevented the transmission of important information from up-river stations to the district center at Louisville, Ky. The crest stages occurred on December 25 and 26, and the crest of 34.8 feet at High Bridge, Ky., exceeded that of March 27, 1913, by 0.2 foot.

Losses were not very heavy, a total of only $43,000 being reported, while much personal property and merchandise was saved through the warnings.

*Other Rivers of Kentucky and West Virginia.*—There were two rises, both moderate, one on December 22, and the other on December 26–28. Flood stages were approximated only, and there was little or no damage, although there was a little local flooding in Williamson, W. Va., from backwaters of the Tug Fork of the Big Sandy River through the city sewers.

*Ohio River.*—There were corresponding rises in the Ohio River but none of much consequence above Cincinnati, Ohio. The nearest approach to flood conditions was below the mouth of the Kentucky River, and from Cloverport, Ky., to Shawneetown, Ill., the Ohio River was in moderate flood, beginning with December 28, and was approaching the flood stage at points below, the gage at Cairo, Ill., reading 44 feet on December 31, while New Madrid, Mo., on the Mississippi River, reported 33.3 feet. Report on this flood will also be made later.

*Atlantic drainage.*—Nothing of special interest transpired. There were small local floods in the rivers of southern Virginia, eastern North Carolina, and central and western South Carolina. These floods were well forecast and no damage was reported.

*East Gulf drainage.*—There was a moderate flood in the Coosa and Cahaba Rivers of Alabama during the closing days of the month. The heavy general rains heretofore referred to were responsible for the floods, which were not sufficient to bring the Alabama River to flood stage. Local warnings were issued at the proper time. The following comment was made by Mr. P. H. Smyth, official in charge of the Weather Bureau Office, Montgomery, Ala.

> The rains during the period mentioned were only moderate in the Tallapoosa basin, and the rain which fell above upper Tallassee was held in Martin Lake, above Martin Dam. No water from Martin Lake entered the Tallapoosa River below Martin Dam except that which passed through the turbines of the power plant at the dam.
>
> Martin Lake has a storage capacity of seventy (70) billion cubic feet. On January 1, 1927, there were stored twenty-three (23) billion cubic feet of water, and it is believed therefore that the stream flow of the Tallapoosa River below Tallassee will be practically constant during the spring of 1927, as far as the rainfall above Martin Dam is concerned.
>
> During the rise the power plants of the Alabama Power Co. at Lock No. 12, and Mitchell Dam, Coosa River, 69 and 57 miles, respectively, above Montgomery, Ala., were so operated as to regulate the stream flow, and consequently the stages reached at places below the dams were much lower than they otherwise would have been.
>
> The Weather Bureau Office at Montgomery kept in touch with the operating department of the Alabama Power Co. through the Montgomery branch, and being governed by the information received, issued no flood warnings for places on the lower Coosa and upper Alabama Rivers. The information received from the power company was of much value to persons on the upper Alabama who had cattle and stock in the lowlands, as they were saved unnecessary expense and trouble of moving them.

The flood in the Tombigbee and Black Warrior Rivers of Alabama and Mississippi was more serious and was still in progress at the close of the month. Report will be made later.

The floods in the rivers of the Pascagoula system of Mississippi were more moderate and Pearl River only was in flood. This flood continued at the end of the month, as did also the flood in the Yazoo River of Mississippi. The latter flood was very severe over the upper reaches.

*Illinois River.*—The Illinois River fell below the flood stage of 12 feet at Pearl, Ill., during December 27, marking the end of the flood that had prevailed since the early days of September, 1926. This flood was discussed in the MONTHLY WEATHER REVIEW for October, 1926.

Local floods in the Little Red and Petit Jean Rivers of Arkansas were not of consequence. However, warnings of a decided rise were distributed along the White River from Calico Rock southward in time to permit the removal of livestock from the bottoms. Some corn and cotton inside the levees were destroyed.

An important flood occurred in the upper Ouachita Basin of southwestern Arkansas during the last decade of the year. An average rainfall on December 20–21 of 4.57 inches, followed by several days of substantial rains, caused this flood which at Camden, Ark., reached a stage of 38.5 feet, 8.5 feet above the flood stage, at 6 p. m., December 25. Warnings were first issued on December 21.

A woman was drowned in the Little Missouri River near Prescott, Ark., and the reported loss and damage aggregated $75,850, of which $14,850 was in farm property and livestock. The greater losses occurred along the Little Missouri River and the Ouachita River in the vicinity of Arkadelphia, Ark. A considerable quantity of livestock was saved through the warnings.

The same general and heavy rains caused floods in the Little River of Arkansas and Sulphur River of Texas. There was also a decided rise in the Red River, but no approach to flood stage, except at Fulton, Ark., where the crest stage of 27.5 feet on December 25, was only 0.5 foot below the flood stage. Ample warnings, beginning with December 21, were issued for these floods, and the reported value of property saved was $33,000, not including the Red River proper, for which no figures could be obtained. The total of the reported losses was $25,350.

*Trinity River of Texas.*—The Trinity River was in moderate flood at Trinidad, Tex., from December 23, 1926, to January 1, 1927, and at Liberty, Tex., from December 28 to 31. Timely warnings permitted the saving of all movable property.

*Ice service.*—On December 20, 1926, there was inaugurated over the Ohio River Basin, the Missouri River east of Kansas City, Mo., and the Mississippi River from the mouth of the Missouri to the mouth of the Ohio, a daily ice reporting service, mainly in the interest of navigation but also for the benefit of other interests that might be affected by ice conditions. Through an interlocking telegraph system, daily reports are exchanged between Weather Bureau stations, reports received from sub-

stations, and a daily ice summary and forecast issued through the medium of bulletins, radio, telegraph, telephone and newspapers. It is hoped and expected that the new service will be of great value to those interested.

| River and station | Flood stage | Above flood stages—dates From— | Above flood stages—dates To— | Crest Stage | Crest Date |
|---|---|---|---|---|---|
| **ATLANTIC DRAINAGE** | *Feet* | | | *Feet* | |
| Saluda: Chappells, S. C | 14 | 30 | 30 | 14.3 | 30 |
| James: Columbia, Va | 18 | 27 | 28 | 21.0 | 28 |
| Roanoke: Weldon, N. C | 30 | 29 | (1) | 35.7 | 30 |
| **EAST GULF DRAINAGE** | | | | | |
| Coosa: Gadsden, Ala | 22 | 28 | (1) | 23.9 | 29 |
| Cahaba: Centerville, Ala | 25 | 26 | 26 | 26.5 | 26 |
| Black Warrior: Lock, No. 10, Tuscaloosa, Ala | 46 | 25 | (1) | 61.8 | 26 |
| Tombigbee: | | | | | |
| Aberdeen, Miss | 33 | 25 | (1) | 39.2 | 27 |
| Columbus, Miss | 33 | 27 | 31 | 34.4 | 28 |
| Lock, No. 4, Demopolis, Ala | 39 | 26 | (1) | 66.3 | Jan. 5 |
| Pearl: | | | | | |
| Edinburg, Miss | 21 | 31 | (1) | (2) | |
| Jackson, Miss | 20 | 30 | (1) | (2) | |
| **MISSISSIPPI DRAINAGE** | | | | | |
| Ohio: | | | | | |
| Dam, No. 44, Leavenworth, Ind | 48 | 28 | (1) | 50.8 | 30-31 |
| Cloverport, Ky | 40 | 28 | (1) | 42.8 | 31 |
| Evansville, Ind | 35 | 27 | (1) | (2) | |
| Dam, No. 48, Cypress, Ind | 35 | 28 | (1) | (2) | |
| Mount Vernon, Ind | 35 | 28 | (1) | (2) | |
| Shawneetown, Ill | 35 | 29 | (1) | (2) | |
| Guyandotte: Logan, W. Va | 20 | 22 | 22 | 20.2 | 22 |
| Big Sandy, Levisa Fork: Pikeville, Ky | 35 | 22 | 22 | 41.3 | 22 |
| Kentucky: | | | | | |
| Hazard, Ky | 20 | 21 | 21 | 25.0 | 21 |
| Beattyville, Ky | 30 | 22 | 23 | 40.1 | 22 |
| | | 26 | 26 | 30.6 | 26 |
| High Bridge, Ky | 30 | 25 | 27 | 34.8 | 26 |
| Frankfort, Ky | 31 | 25 | 29 | 36.0 | 26 |
| Green-Big Barren: | | | | | |
| Bowling Green, Ky | 20 | 22 | 29 | 36.5 | 23 |
| Munfordville, Ky | 28 | 23 | 28 | 36.9 | 24 |
| Lock, No. 6, Brownsville, Ky | 30 | 23 | (1) | 42.5 | 26 |
| Lock, No. 4, Woodbury, Ky | 33 | 22 | (1) | 49.3 | 27 |
| Lock, No. 2, Rumsey, Ky | 34 | 25 | (1) | 42.3 | 31 |
| Cumberland: Williamsburg, Ky | 22 | 22 | 29 | 26.5 | 26 |
| Burnside, Ky | 50 | 22 | 23 | 56.3 | 22 |
| | | 25 | 27 | 59.3 | 26 |
| Celina, Tenn | 45 | 23 | Jan. 2 | 57.2 | 29 |
| Carthage, Tenn | 40 | 23 | Jan. 4 | 59.1 | 30 |
| Nashville, Tenn | 40 | 22 | Jan. 7 | 56.2 | Jan. 1 |
| Clarksville, Tenn | 46 | 22 | Jan. 9 | 60.0 | Jan. 2 |
| Lock, F, Eddyville, Ky | 57 | 26 | Jan. 11 | 68.5 | Jan. 5 |
| Tennessee: | | | | | |
| Knoxville, Tenn | 12 | 26 | 30 | 14.0 | 29 |
| Rockwood, Tenn | 20 | 25 | 30 | 25.2 | 27 |
| Chattanooga, Tenn | 33 | 26 | (1) | 38.4 | 29-30 |
| Bridgeport, Ala | 24 | 27 | (1) | 28.3 | 30 |
| Guntersville, Ala | 31 | 27 | (1) | 38.3 | 30 |
| Decatur, Ala | 21 | 29 | (1) | 23.2 | Jan. 1 |
| Florence, Ala | 18 | 25 | (1) | 26.6 | 29 |
| Riverton, Ala | 33 | 25 | (1) | (2) | |
| Savannah, Tenn | 40 | 27 | (1) | (2) | |
| Johnsonville, Tenn | 31 | 27 | (1) | (2) | |
| Holston, N Fork: Mendota, Va | 8 | 22 | 22 | 16.2 | 22 |
| Big Pigeon: | | | | | |
| Newport, Tenn | 6 | 26 | 26 | 7.3 | 26 |
| | | 29 | 29 | 6.2 | 29 |
| Rogersville, Tenn | 14 | 23 | 23 | 15.0 | 23 |
| Clinch: | | | | | |
| Speers Ferry, Va | 20 | 22 | 22 | 22.0 | 22 |
| Clinton, Tenn | 25 | 23 | 28 | 32.3 | 24 |
| Little Tennessee: McGhee, Tenn | 20 | 26 | 26 | 20.2 | 26 |
| Hiwassee: Charleston, Tenn | 22 | 29 | 29 | 22.9 | 29 |
| Elk: Fayetteville, Tenn | 14 | 24 | (1) | (4) 25.8 | 28 |
| Duck: Columbia, Tenn | 30 | 25 | 30 | 35.6 | 27 |
| Illinois: | | | | | |
| Henry, Ill | 10 | (3) | 16 | 14.5 | Nov. 22 |
| Peru, Ill | 14 | (3) | 26 | 19.9 | Nov. 19 |
| Peoria, Ill | 18 | (3) | 11 | 21.0 | Nov. 23-24 |
| Havana, Ill | 14 | (3) | 27 | 18.6 | Nov. 29-30 |
| Beardstown, Ill | 14 | (3) | 31 | 20.4 | Nov. 29-30 |
| Pearl, Ill | 12 | (3) | 27 | 16.4 | Nov. 30 |
| Black: Corning, Ark | 11 | 23 | (1) | (2) | |
| Little Red: Dam, No. 1, Judsonia, Ark | | | | 30.0 | 22-23 |
| Arkansas: Yancopin, Ark | 29 | 25 | (1) | (2) | |
| Tallahatchie: Swan Lake, Miss | 25 | 30 | (1) | (2) | |
| Yazoo: Greenwood, Miss | 36 | 30 | (1) | (2) | |
| Sulphur: | | | | | |
| Ringo Crossing, Tex | 20 | 21 | 26 | 27.1 | 22 |
| Finley, Tex | 24 | 24 | (1) | 29.0 | 26 |
| Little: Whitecliffs, Ark | 28 | 23 | 25 | 28.9 | 24 |
| Ouachita: | | | | | |
| Arkadelphia, Ark | 18 | 22 | 23 | 22.5 | 22 |
| Camden, Ark | 30 | 24 | (1) | 38.5 | 25 |
| **WEST GULF DRAINAGE** | | | | | |
| Trinity: | | | | | |
| Trinidad, Tex | 28 | 23 | 23 | 28.0 | 23 |
| | | 25 | Jan. 1 | 30.9 | 29-30 |
| Liberty, Tex | 25 | 28 | 31 | 25.4 | 28 |

[1] Continued at end of month.
[2] Crest occurred after end of month.
[3] Continued from last month.
[4] Estimated.

## MEAN LAKE LEVELS DURING DECEMBER, 1926

By UNITED STATES LAKE SURVEY

[Detroit, Mich., January 4, 1927]

The following data are reported in the "Notice to Mariners" of the above date:

| Data | Lakes[1] Superior | Michigan and Huron | Erie | Ontario |
|---|---|---|---|---|
| Mean level during December, 1926: | *Feet* | *Feet* | *Feet* | *Feet* |
| Above mean sea level at New York | 601.68 | 578.26 | 571.45 | 245.42 |
| Above or below— | | | | |
| Mean stage of November, 1926 | −0.07 | +0.04 | −0.07 | +0.18 |
| Mean stage of December, 1925 | +1.43 | +0.72 | +1.06 | +0.87 |
| Average stage for December, last 10 years | −0.34 | −1.35 | −0.08 | +0.23 |
| Highest recorded December stage | −1.45 | −4.32 | −2.08 | −2.19 |
| Lowest recorded December stage | +1.43 | +0.72 | +1.06 | +1.99 |
| Average departure (since 1860) of the December level from the November level | −0.27 | −0.22 | −0.08 | −0.09 |

[1] Lake St. Clair's level: In December, 1926, 574.05 feet.

## EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, DECEMBER, 1926

By J. B. KINCER

*General summary.*—The first part of the month over the northern section of the country was generally unfavorable for outdoor work and seasonal farm operations made little progress. The frequent snows during this period hampered movement of crops to market, but they were favorable in protecting the grain fields against the cold waves which overspread northern areas. In the South, however, the weather permitted farm work to proceed practically unimpeded and winter crops and outdoor operations made good advance.

About the middle of December precipitation was heavy over some eastern districts, but more moisture was still generally needed in most southeastern areas. In the northwest a continuation of cold weather and high winds was unfavorable for livestock, but the frozen ground in the interior valley States made conditions better for gathering the corn that was still out.

Toward the latter part of the month precipitation was was heavy and in some places excessive over the lower Ohio and Mississippi Valleys, with much flooding, and much sleet and glaze was reported from the upper Ohio Valley and Lake region. Rains were beneficial in the Middle Atlantic States, but elsewhere the heavy precipitation prevented seasonal farm operations and caused some local damage. A good snow cover for winter grains and grass wasreported from most sections and much of the western range was covered. The coldest weather of the season was experienced in some parts of the Great Basin and some injury by cold was indicated from the South.

*Small grains.*—In the more northern districts east of the Great Plains winter wheat was generally well protected by snow during most of December, but in some western sections the ground was mostly bare. The absence of a good snow cover during the cold wave the second week caused some anxiety, but apparently no material harm resulted. In the southwestern sections of the Wheat Belt there was a continued absence of moisture and some injury resulted to the crop by drifting soil. The mostly mild weather in the South was generally favorable for winter grain crops.

*Corn.*—During the first part of the month husking and cribbing corn made slow progress due to the continued wet fields and mostly unfavorable weather. There was considerable of this work remaining to be done and husking did not get well under way until the third week, when frozen ground facilitated operations. Cribbing was

practically completed in the central Great Plains, but some corn remained to be cribbed in Missouri at the close of the month and some remained out in other sections.

*Cotton.*—Picking and ginning cotton made generally good progress in the Cotton Belt until the rains in the northwestern portion, where considerable cotton remained out at the beginning of December. Frequent rains during the second week made continued unfavorable conditions and there was further damage to staple, particularly in the northwest. During the latter part of the month picking the remaining crop made generally slow advance due to wet fields and continued rains and much cotton was reported pounded out by sleet and rain; considerable cotton remained in the fields in the northwest at the close.

*Miscellaneous crops.*—Pastures remained poor in some sections of the East, but the range continued in about normal condition in the more western districts with ample snow for water reported in some areas and other sections open. Heavy feeding continued in some portions, but others, especially the northern Great Plains, had favorable weather and livestock were able to range freely. Winter truck continued to do well in most districts, although there was some slight injury by frost. Citrus did well generally and no harm was reported, although it was somewhat too warm for this crop in Florida.

## CLIMATOLOGICAL TABLES[1]

### CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

*Condensed climatological summary of temperature and precipitation by sections, December, 1926*

| Section | Temperature | | | | | | | | Precipitation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Section average | Departure from the normal | Monthly extremes | | | | | | Section average | Departure from the normal | Greatest monthly | | Least monthly | |
| | | | Station | Highest | Date | Station | Lowest | Date | | | Station | Amount | Station | Amount |
| | ° F. | ° F. | | ° F. | | | ° F. | | In. | In. | | In. | | In. |
| Alabama | 52.0 | +4.7 | Evergreen | 87 | 12 | 5 stations | 15 | [2] 16 | 5.92 | +1.07 | Florence | 14.59 | Silverhill | 1.11 |
| Arizona | 43.4 | −1.1 | 2 stations | 85 | 1 | Springerville | −28 | 27 | 3.02 | +1.69 | Crown King | 11.53 | Lewis Springs | 0.45 |
| Arkansas | 43.3 | +0.8 | 2 stations | 79 | [2] 4 | Mammoth Spring | −3 | 26 | 7.15 | +3.10 | Portland | 12.43 | Gilbert | 2.53 |
| California | 45.3 | −0.8 | King City | 89 | 1 | Helm Creek | −15 | 25 | 2.38 | −1.79 | Cuyamaca | 16.52 | Haiwee | 0.00 |
| Colorado | 23.5 | −1.4 | 4 stations | 75 | [2] 2 | Hermit | −41 | 24 | 1.09 | +0.07 | Cascade | 4.12 | Garnett | 0.04 |
| Florida | 63.7 | +4.1 | 2 stations | 89 | [2] 15 | Arcadia | 23 | 31 | 0.99 | −2.10 | DeFuniak Springs | 2.95 | Everglades | 0.05 |
| Georgia | 51.7 | +4.1 | Alapaha | 85 | 13 | Blue Ridge | 12 | 3 | 3.89 | −0.37 | Blue Ridge | 13.22 | Savannah | 0.77 |
| Idaho | 25.7 | −0.2 | Glenns Ferry | 64 | 1 | Stanley | −37 | 14 | 1.82 | −0.11 | Roland | 4.88 | Lifton | 0.12 |
| Illinois | 29.1 | −1.4 | Harrisburg | 68 | 3 | 3 stations | −9 | 14 | 1.41 | −0.85 | Cairo | 4.15 | Elgin | 0.40 |
| Indiana | 29.9 | −2.2 | Marengo | 67 | 3 | Cambridge City | −9 | 30 | 1.96 | −0.94 | Rome | 4.45 | Farmersburg | 0.74 |
| Iowa | 21.9 | −2.2 | Chariton | 58 | 1 | 2 stations | −21 | 14 | 1.06 | −0.08 | Forest City | 2.42 | Chariton | 0.28 |
| Kansas | 31.8 | +0.3 | Lakin | 77 | 2 | 2 stations | −14 | 15 | 0.90 | −0.03 | Columbus | 2.97 | Bazaar | 0.13 |
| Kentucky | 37.8 | +0.2 | Williamsburg | 75 | 13 | Hindman | 5 | 16 | 6.01 | +1.93 | Burnside | 11.31 | Lockport | 2.73 |
| Louisiana | 56.7 | +4.9 | Schriever | 86 | 9 | Robeline | 15 | 16 | 5.84 | +0.66 | Monroe | 13.71 | Burrwood | 0.96 |
| Maryland-Delaware | 32.1 | −3.0 | Newburg, Md | 62 | 8 | Oakland, Md | −16 | 18 | 3.19 | −0.10 | Oakland, Md | 5.73 | Keedysville, Md | 2.16 |
| Michigan | 22.0 | −3.0 | Monroe | 54 | 13 | 2 stations | −33 | 18 | 1.57 | −0.53 | Painesdale | 3.60 | Harbor Beach | 0.62 |
| Minnesota | 11.0 | −4.0 | Lynd | 50 | 11 | Hallock | −36 | 14 | 0.99 | +0.26 | Grand Marais | 1.95 | Alexandria | 0.17 |
| Mississippi | 51.7 | +3.9 | Poplarville | 85 | 9 | Holly Springs | 14 | 16 | 9.49 | +4.16 | Water Valley | 19.35 | Pearlington | 2.20 |
| Missouri | 32.6 | −1.3 | 2 stations | 75 | 4 | Greenville | −12 | 26 | 2.18 | +0.15 | New Madrid | 6.74 | Saint Charles | 0.55 |
| Montana | 21.4 | −0.5 | Sun River Canyon | 74 | 10 | Conway's Ranch | −36 | 14 | 0.79 | −0.13 | Hebgen Dam | 3.74 | 2 stations | 0.05 |
| Nebraska | 25.0 | −0.8 | 2 stations | 70 | 2 | Hay Springs | −25 | 15 | 0.63 | −0.11 | Walthill | 1.60 | Arcadia | 0.00 |
| Nevada | 30.6 | −1.2 | Alamo | 75 | 1 | San Jacinto | −24 | 24 | 0.66 | −0.28 | Lamoille | 1.81 | 2 stations | 0.14 |
| New England | 21.4 | −5.0 | North Grovenor Dale, Conn. | 55 | 1 | Garfield, Vt | −21 | 5 | 2.93 | −0.42 | Colchester, Conn | 5.21 | Cornwall, Vt | 0.95 |
| New Jersey | 28.4 | −4.4 | 2 stations | 52 | [2] 1 | Somerville | −7 | 7 | 3.44 | −0.54 | Chatham | 4.74 | Layton | 1.67 |
| New Mexico | 33.0 | −0.3 | Pastura | 83 | 1 | Elizabethtown | −34 | 25 | 1.53 | +0.73 | Cloverdale | 5.94 | Miami | 0.18 |
| New York | 21.0 | −4.7 | Ohioville | 61 | 14 | Philadelphia | −32 | 18 | 2.41 | −0.57 | Philadelphia | 4.90 | Andover | 0.86 |
| North Carolina | 43.8 | +1.3 | Chadbourn | 77 | 25 | 2 stations | 7 | 19 | 4.17 | +0.28 | Andrews | 13.12 | New Holland | 1.13 |
| North Dakota | 9.2 | −3.8 | Grafton | 55 | 29 | Dunseith | −36 | 14 | 0.57 | +0.03 | Fort Yates | 1.50 | Maddock | 0.10 |
| Ohio | 29.5 | −1.8 | 3 stations | 68 | 13 | Millport | −11 | 18 | 2.38 | −0.48 | Dam No. 28 | 4.94 | Catawba Island | 1.23 |
| Oklahoma | 40.3 | +1.2 | Waurika | 84 | 3 | Hooker | −4 | 15 | 2.92 | +1.35 | Smithville | 7.66 | Kenton | 0.52 |
| Oregon | 34.2 | +0.2 | Cottage Grove | 73 | 17 | Ukiah | −26 | 14 | 3.93 | −0.45 | Bull Run Lake | 17.94 | Andrews | 0.44 |
| Pennsylvania | 27.3 | −3.8 | Uniontown | 62 | 13 | West Bingham | −20 | 7 | 2.58 | −0.65 | Unity Reservoir | 4.61 | Lloyd | 0.90 |
| South Carolina | 48.7 | +2.1 | Georgetown | 82 | 22 | Caesar's Head | 13 | [2] 16 | 3.59 | +0.12 | Caesar's Head | 8.00 | Summerville | 0.69 |
| South Dakota | 19.2 | −0.6 | Bellefourche | 66 | 31 | Oelrichs | −30 | 14 | 0.39 | −0.21 | Milbank | 1.42 | Ottumwa | T. |
| Tennessee | 41.7 | +1.1 | Etowah | 74 | 13 | Tazewell | 4 | 16 | 10.69 | +6.31 | Madison | 15.57 | Embreeville | 4.85 |
| Texas | 49.8 | +0.0 | Mission | 89 | 4 | 2 stations | 3 | [2] 13 | 4.01 | +1.85 | Rockland | 11.60 | O 2 Ranch | 0.42 |
| Utah | 25.9 | −0.6 | Springdale | 73 | 1 | Castle Rock | −25 | 15 | 1.15 | −0.04 | Big Plains | 4.65 | 2 stations | T. |
| Virginia | 36.8 | −1.5 | Diamond Springs | 70 | 26 | 4 stations | 0 | [2] 18 | 4.88 | +1.74 | Mendota | 9.24 | Mount Weather | 1.79 |
| Washington | 32.0 | −0.1 | Centralia | 69 | 1 | Cle Elum | −15 | 14 | 5.04 | −0.87 | Forks | 18.83 | Quincy | 0.58 |
| West Virginia | 33.9 | +0.3 | Williamson | 72 | 3 | 2 stations | −14 | 18 | 5.10 | +1.59 | Pickens | 10.57 | Vandalia | 1.65 |
| Wisconsin | 16.3 | −3.9 | 2 stations | 51 | [2] 12 | Prentice | −31 | 25 | 1.55 | +0.21 | Plum Island | 3.02 | Beloit | 0.53 |
| Wyoming | 21.1 | +0.3 | Wheatland | 68 | 2 | Riverside | −49 | 14 | 0.51 | −0.29 | Dome Lake | 1.82 | Powell | 0.01 |
| Alaska [November] | 30.5 | +6.3 | Hydaburg | 63 | 7 | Fort Yukon | −41 | 30 | 4.38 | −2.75 | Latouche | 23.23 | Fort Yukon | 0.03 |
| Hawaii | 71.9 | +2.0 | Waianae | 91 | 8 | Volcano Observatory. | 46 | 31 | 5.64 | −3.84 | Hiloa - Manawaiopuna Divide. | 32.00 | Kaanapali | T. |
| Porto Rico | 74.7 | +0.1 | 2 stations | 94 | [2] 9 | 2 stations | 52 | [2] 26 | 2.30 | −2.32 | Barros | 6.79 | Ponce | 0.05 |

[1] For description of tables and charts, see REVIEW, January, 1926, page 32.

[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau Stations, December, 1926*

| Districts and stations | Elevation of instruments: Barometer above sea level | Thermometer above ground | Anemometer above ground | Pressure: Station, reduced to mean of 24 hours | Sea level, reduced to mean of 24 hours | Departure from normal | Temperature of the air: Mean max. + mean min. ÷ 2 | Departure from normal | Maximum | Date | Mean maximum | Minimum | Date | Mean minimum | Greatest daily range | Mean wet thermometer | Mean temperature of the dew point | Mean relative humidity | Precipitation: Total | Departure from normal | Days with 0.01, or more | Wind: Total movement | Prevailing direction | Maximum velocity: Miles per hour | Direction | Date | Clear days | Partly cloudy days | Cloudy days | Average cloudiness, tenths | Total snowfall | Snow, sleet, and ice on ground at end of month |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ft. | Ft. | Ft. | In. | In. | In. | °F. | °F. | °F. | | °F. | °F. | | °F. | °F. | °F. | °F. | % | In. | In. | | Miles | | | | | | | | 0-10 | In. | In. |
| ***New England*** | | | | | | | 24.8 | −4.6 | | | | | | | | | | 76 | 2.87 | −0.5 | | | | | | | | | | 6.3 | | |
| Eastport | 76 | 67 | 85 | 29.87 | 29.96 | −.02 | 22.4 | −3.9 | 45 | 29 | 30 | −2 | 5 | 15 | 26 | 21 | 16 | 75 | 3.09 | −0.9 | 20 | 10,066 | nw. | 47 | ne. | 6 | 6 | 8 | 17 | 6.7 | 20.0 | 0.1 |
| Greenville, Me. | 1,070 | 6 | ---- | 28.80 | 30.01 | ---- | 15.3 | ---- | 39 | 14 | 23 | −8 | 5 | 8 | 25 | ---- | ---- | ---- | 2.85 | ---- | 14 | 7,058 | nw. | 30 | nw. | 6 | 8 | 10 | 13 | ---- | 28.5 | ---- |
| Portland, Me. | 103 | 82 | 117 | 29.92 | 30.06 | +.03 | 23.6 | −4.0 | 51 | 14 | 30 | 0 | 19 | 17 | 23 | 21 | 16 | 73 | 3.46 | −0.2 | 12 | 6,333 | nw. | 37 | nw. | 4 | 12 | 3 | 16 | 5.9 | 19.8 | 3.0 |
| Concord | 289 | 70 | 79 | 29.71 | 30.04 | −.02 | 20.5 | −6.3 | 47 | 14 | 30 | −1 | 18 | 11 | 33 | ---- | ---- | ---- | 2.16 | −1.2 | 11 | 3,174 | nw. | 19 | nw. | 19 | 9 | 9 | 13 | 5.9 | 20.1 | 6.0 |
| Burlington | 403 | 11 | 48 | 29.62 | 30.09 | +.04 | 18.2 | −6.2 | 39 | 14 | 24 | −6 | 5 | 12 | 23 | ---- | ---- | ---- | 1.00 | −0.7 | 14 | 8,888 | s. | 46 | s. | 24 | 1 | 7 | 23 | 8.6 | 10.3 | 4.2 |
| Northfield | 876 | 12 | 60 | 29.09 | 30.09 | +.04 | 14.6 | −5.8 | 45 | 14 | 24 | −14 | 7 | 5 | 36 | 14 | 11 | 86 | 1.08 | −1.6 | 14 | 4,884 | n. | 27 | n. | 2 | 1 | 11 | 19 | 8.0 | 14.5 | 7.6 |
| Boston | 125 | 115 | 188 | 29.90 | 30.05 | .00 | 28.6 | −3.9 | 51 | 14 | 35 | 4 | 5 | 21 | 28 | 25 | 20 | 70 | 3.96 | +0.6 | 11 | 7,904 | w. | 35 | nw. | 2 | 13 | 5 | 13 | 5.3 | 24.2 | 1.7 |
| Nantucket | 12 | 14 | 90 | 30.00 | 30.02 | −.03 | 33.0 | −2.8 | 51 | 1 | 40 | 8 | 19 | 26 | 27 | 31 | 29 | 86 | 3.22 | −0.4 | 15 | 11,928 | nw. | 61 | e. | 5 | 7 | 7 | 17 | 6.6 | 9.5 | 0.0 |
| Block Island | 26 | 11 | 46 | 30.01 | 30.04 | −.02 | 31.2 | −4.8 | 52 | 28 | 38 | 8 | 18 | 25 | 28 | 29 | 25 | 75 | 2.47 | −1.4 | 9 | 15,683 | nw. | 59 | nw. | 18 | 7 | 7 | 17 | 6.6 | 6.5 | 0.0 |
| Providence | 160 | 215 | 251 | 29.87 | 30.06 | .00 | 27.7 | −3.9 | 50 | 28 | 36 | 4 | 19 | 20 | 36 | 25 | 19 | 70 | 2.75 | −1.1 | 9 | 9,981 | nw. | 46 | nw. | 2 | 13 | 6 | 12 | 5.2 | 16.5 | 0.1 |
| Hartford | 159 | 122 | ---- | 29.90 | 30.09 | +.02 | 25.4 | −4.4 | 45 | 14 | 32 | 4 | 18 | 18 | 27 | ---- | ---- | ---- | 3.35 | −0.2 | 10 | ---- | nw. | ---- | ---- | | 10 | 7 | 14 | 5.5 | 20.7 | 6.6 |
| New Haven | 106 | 74 | 153 | 29.97 | 30.09 | +.02 | 27.2 | −4.3 | 47 | 14 | 34 | 6 | 18 | 20 | 27 | 25 | 20 | 76 | 4.99 | +1.3 | 11 | 7,122 | n. | 35 | n. | 2 | 8 | 12 | 11 | 5.4 | 14.5 | 1.8 |
| ***Middle Atlantic States*** | | | | | | | 32.0 | −3.5 | | | | | | | | | | 76 | 3.49 | +0.4 | | | | | | | | | | 6.5 | | |
| Albany | 97 | 102 | 115 | 30.00 | 30.11 | +.03 | 21.5 | −7.0 | 41 | 21 | 29 | −2 | 7 | 14 | 26 | 20 | 17 | 85 | 1.97 | −0.6 | 9 | 5,234 | s. | 26 | n. | 4 | 7 | 6 | 18 | 6.6 | 19.2 | 6.0 |
| Binghamton | 871 | 10 | 84 | 29.10 | 30.10 | +.01 | 23.5 | −4.7 | 44 | 14 | 31 | −4 | 19 | 16 | 32 | ---- | ---- | ---- | 2.40 | 0.0 | 19 | 4,150 | nw. | 26 | nw. | 2 | 5 | 7 | 19 | 7.5 | 25.6 | 7.5 |
| New York | 314 | 414 | 454 | 29.75 | 30.10 | +.01 | 29.2 | −5.8 | 50 | 14 | 36 | 7 | 18 | 22 | 28 | 27 | 20 | 69 | 3.72 | +0.3 | 14 | 12,889 | nw. | 68 | nw. | 2 | 7 | 12 | 12 | 6.1 | 10.2 | T. |
| Harrisburg | 374 | 94 | 104 | 29.73 | 30.15 | +.03 | 29.2 | −3.5 | 45 | 1 | 36 | 8 | 18 | 23 | 25 | 26 | 20 | 70 | 2.60 | 0.0 | 12 | 5,106 | nw. | 30 | nw. | 1 | 8 | 5 | 18 | 6.4 | 2.6 | T. |
| Philadelphia | 114 | 123 | 190 | 30.00 | 30.13 | +.02 | 32.3 | −4.0 | 50 | 1 | 38 | 12 | 18 | 26 | 23 | 30 | 26 | 78 | 3.54 | +0.5 | 10 | 7,586 | n. | 38 | n. | 4 | 8 | 8 | 15 | 6.2 | 4.4 | 0.0 |
| Reading | 325 | 81 | 98 | 29.76 | 30.13 | ---- | 29.2 | ---- | 45 | 1 | 36 | 7 | 18 | 23 | 25 | 26 | 22 | 76 | 2.10 | −1.2 | 13 | 4,655 | nw. | 28 | nw. | 2 | 8 | 7 | 16 | 6.7 | 5.1 | 0.1 |
| Scranton | 805 | 111 | 119 | 29.22 | 30.12 | +.02 | 25.0 | −5.7 | 42 | 13 | 32 | 3 | 19 | 18 | 30 | 23 | 21 | 84 | 2.06 | −0.6 | 18 | 5,129 | s. | 25 | w. | 1 | 5 | 10 | 16 | 7.1 | 13.1 | 2.2 |
| Atlantic City | 52 | 37 | 172 | 30.05 | 30.11 | +.01 | 33.0 | −3.4 | 51 | 28 | 40 | 9 | 19 | 26 | 26 | 30 | 26 | 77 | 3.71 | 0.0 | 15 | 12,347 | nw. | 49 | nw. | 2 | 10 | 7 | 14 | 5.9 | 0.6 | 0.0 |
| Cape May | 17 | 13 | 49 | | | | 33.4 | −4.6 | 50 | 8 | 40 | 11 | 18 | 26 | 27 | ---- | ---- | ---- | 3.93 | ---- | 13 | ---- | n. | ---- | ---- | | ---- | ---- | ---- | ---- | 0.2 | 0.0 |
| Sandy Hook | 22 | 10 | 55 | 30.07 | 30.10 | ---- | 29.7 | ---- | 45 | 14 | 35 | 10 | 18 | 24 | 24 | 27 | 22 | 73 | 3.58 | ---- | 13 | 12,710 | nw. | 60 | nw. | 2 | 7 | 7 | 17 | 6.2 | 9.0 | T. |
| Trenton | 190 | 159 | 183 | 29.90 | 30.11 | ---- | 28.8 | ---- | 47 | 1 | 36 | 9 | 19 | 22 | 26 | 26 | 22 | 78 | 3.00 | −0.2 | 12 | 7,383 | nw. | 36 | nw. | 16 | 8 | 10 | 13 | 6.0 | 7.2 | T. |
| Baltimore | 123 | 100 | 215 | 29.99 | 30.13 | .00 | 33.6 | −3.6 | 51 | 14 | 40 | 11 | 18 | 28 | 24 | 30 | 25 | 71 | 2.89 | −0.2 | 12 | 6,955 | nw. | 36 | nw. | 2 | 10 | 4 | 17 | 6.1 | 0.7 | 0.0 |
| Washington | 112 | 62 | 85 | 30.00 | 30.13 | .00 | 33.8 | −2.8 | 50 | 8 | 40 | 10 | 18 | 27 | 23 | 30 | 25 | 73 | 3.02 | −0.1 | 11 | 4,748 | n. | 35 | nw. | 2 | 7 | 6 | 18 | 6.8 | 1.0 | T. |
| Cape Henry | 18 | 8 | 54 | 30.09 | 30.13 | ---- | 41.0 | ---- | 68 | 26 | 48 | 20 | 18 | 34 | 32 | 38 | 34 | 80 | 5.09 | +1.7 | 13 | 11,009 | sw. | 55 | n. | 6 | 8 | 8 | 15 | 6.5 | 0.0 | 0.0 |
| Lynchburg | 681 | 153 | 188 | 29.37 | 30.14 | .00 | 37.9 | −1.6 | 62 | 4 | 46 | 10 | 19 | 30 | 28 | 33 | 28 | 71 | 4.99 | +1.7 | 11 | 5,500 | w. | 44 | nw. | 26 | 9 | 8 | 14 | 6.3 | T. | 0.0 |
| Norfolk | 91 | 170 | 205 | 30.03 | 30.13 | .00 | 41.4 | −1.7 | 68 | 26 | 49 | 20 | 19 | 34 | 33 | 37 | 32 | 74 | 4.52 | +1.0 | 14 | 9,820 | n. | 50 | nw. | 26 | 8 | 5 | 18 | 6.8 | T. | 0.0 |
| Richmond | 144 | 11 | 52 | 29.98 | 30.14 | .00 | 37.8 | −2.0 | 65 | 4 | 46 | 13 | 19 | 30 | 31 | 33 | 29 | 77 | 4.56 | +1.6 | 14 | 5,787 | ne. | 26 | w. | 8 | 9 | 6 | 16 | 6.2 | T. | 0.0 |
| Wytheville | 2,304 | 49 | 55 | 27.67 | 30.13 | −.02 | 36.4 | +1.1 | 60 | 13 | 44 | 12 | 16 | 29 | 30 | 33 | 29 | 81 | 5.67 | +1.9 | 12 | 5,541 | w. | 44 | w. | 26 | 6 | 9 | 16 | 6.8 | 1.5 | T. |
| ***South Atlantic States*** | | | | | | | 49.7 | +2.3 | | | | | | | | | | 77 | 2.02 | −1.4 | | | | | | | | | | 5.5 | | |
| Asheville | 2,253 | 70 | 84 | 27.72 | 30.14 | −.02 | 40.4 | +2.6 | 67 | 13 | 49 | 17 | 16 | 31 | 34 | 36 | 32 | 78 | 3.19 | +0.1 | 10 | 7,597 | se. | 35 | n. | 26 | 8 | 10 | 13 | 6.2 | 0.2 | T. |
| Charlotte | 779 | 55 | 62 | 29.28 | 30.14 | −.02 | 44.4 | +1.4 | 70 | 10 | 53 | 18 | 19 | 36 | 32 | 39 | 34 | 74 | 3.86 | 0.0 | 13 | 3,842 | sw. | 23 | sw. | 26 | 7 | 10 | 14 | 6.1 | 0.0 | 0.0 |
| Hatteras | 11 | 11 | 50 | 30.09 | 30.11 | −.02 | 48.6 | −1.5 | 66 | 29 | 56 | 27 | 19 | 41 | 26 | 45 | 43 | 84 | 1.54 | −3.6 | 13 | 11,706 | n. | 44 | n. | 30 | 12 | 7 | 12 | 5.7 | 0.0 | 0.0 |
| Raleigh | 376 | 103 | 110 | 29.72 | 30.14 | −.01 | 43.0 | 0.0 | 68 | 26 | 56 | 16 | 19 | 34 | 32 | 39 | 35 | 79 | 3.43 | +0.3 | 11 | 5,610 | sw. | 30 | sw. | 26 | 8 | 7 | 16 | 6.3 | 0.0 | 0.0 |
| Wilmington | 78 | 81 | 91 | 30.06 | 30.14 | −.01 | 50.8 | +1.7 | 74 | 13 | 61 | 19 | 19 | 41 | 34 | 46 | 42 | 76 | 1.42 | −1.7 | 6 | 5,597 | sw. | 27 | sw. | 26 | 11 | 8 | 12 | 5.2 | T. | 0.0 |
| Charleston | 48 | 11 | 92 | 30.09 | 30.14 | −.01 | 54.4 | +2.7 | 79 | 22 | 62 | 28 | 19 | 46 | 25 | 50 | 47 | 81 | 0.92 | −2.2 | 6 | 7,718 | sw. | 30 | sw. | 26 | 11 | 10 | 10 | 5.4 | 0.0 | 0.0 |
| Columbia, S. C. | 351 | 41 | 57 | 29.75 | 30.15 | −.01 | 50.3 | +3.1 | 72 | 25 | 60 | 23 | 19 | 41 | 35 | 44 | 38 | 70 | 1.74 | −1.2 | 10 | 5,256 | w. | 37 | sw. | 21 | 13 | 10 | 8 | 5.0 | T. | 0.0 |
| Due West | 711 | 10 | 55 | 29.38 | 30.17 | ---- | 45.8 | ---- | 69 | 25 | 55 | 22 | 19 | 37 | 31 | ---- | ---- | ---- | 4.24 | ---- | 14 | 6,333 | sw. | 38 | w. | 26 | 8 | 12 | 11 | 5.8 | 0.0 | 0.0 |
| Greenville, S. C. | 1,039 | 139 | 146 | 29.00 | 30.12 | ---- | 45.4 | +3.2 | 69 | 22 | 53 | 20 | 19 | 37 | 24 | 40 | 35 | 74 | 6.56 | ---- | 13 | 6,519 | ne. | 35 | sw. | 25 | 11 | 6 | 14 | 5.8 | 0.0 | 0.0 |
| Augusta | 182 | 62 | 79 | 29.94 | 30.13 | −.03 | 51.6 | +3.5 | 79 | 25 | 62 | 26 | 19 | 42 | 37 | 47 | 44 | 82 | 1.75 | −1.7 | 9 | 4,171 | nw. | 28 | sw. | 21 | 11 | 11 | 9 | 5.0 | 0.0 | 0.0 |
| Savannah | 65 | 150 | 194 | 30.07 | 30.13 | −.01 | 56.4 | +4.0 | 78 | 13 | 66 | 31 | 19 | 47 | 34 | 50 | 46 | 75 | 0.77 | −2.3 | 6 | 9,170 | ne. | 34 | nw. | 29 | 15 | 4 | 12 | 4.8 | 0.0 | 0.0 |
| Jacksonville | 43 | 209 | 245 | 30.09 | 30.14 | .00 | 60.9 | +4.6 | 79 | 14 | 69 | 33 | 30 | 52 | 27 | 54 | 51 | 79 | 1.58 | −1.4 | 9 | 9,091 | sw. | 39 | sw. | 28 | 11 | 11 | 9 | 5.0 | 0.0 | 0.0 |
| ***Florida Peninsula*** | | | | | | | 70.8 | +4.3 | | | | | | | | | | 79 | 0.49 | −1.5 | | | | | | | | | | 3.8 | | |
| Key West | 22 | 10 | 64 | 30.06 | 30.08 | .00 | 73.6 | +3.3 | 84 | 14 | 78 | 54 | 31 | 69 | 16 | 67 | 65 | 82 | 0.65 | −1.2 | 4 | 7,421 | ne. | 33 | nw. | 29 | 20 | 9 | 2 | 2.9 | 0.0 | 0.0 |
| Miami | 25 | 71 | 79 | 30.09 | 30.12 | ---- | 72.2 | +4.2 | 84 | 29 | 77 | 43 | 31 | 67 | 25 | 65 | 62 | 74 | 0.23 | −1.8 | 3 | 4,835 | se. | 24 | ne. | 18 | 15 | 14 | 2 | 4.0 | 0.0 | 0.0 |
| Tampa | 35 | 79 | 87 | 30.09 | 30.13 | +.01 | 66.6 | +5.5 | 81 | 14 | 75 | 39 | 31 | 58 | 24 | 60 | 57 | 80 | 0.60 | −1.4 | 5 | 4,628 | e. | 24 | nw. | 29 | 13 | 12 | 6 | 4.3 | 0.0 | 0.0 |
| Titusville | 44 | 5 | ---- | 30.08 | 30.13 | ---- | 66.4 | ---- | 86 | 13 | 77 | 35 | 31 | 56 | 31 | ---- | ---- | ---- | 0.47 | ---- | 4 | ---- | sw. | ---- | ---- | ---- | 13 | 11 | 7 | 4.2 | 0.0 | 0.0 |
| ***East Gulf States*** | | | | | | | 53.5 | +4.0 | | | | | | | | | | 77 | 4.85 | +0.3 | | | | | | | | | | 6.0 | | |
| Atlanta | 1,173 | 190 | 216 | 28.88 | 30.14 | −.02 | 46.3 | +1.6 | 72 | 13 | 54 | 21 | 16 | 38 | 31 | 42 | 38 | 76 | 5.06 | +0.5 | 11 | 9,959 | nw. | 42 | nw. | 25 | 10 | 7 | 14 | 5.7 | 0.0 | 0.0 |
| Macon | 370 | 78 | 87 | 29.74 | 30.15 | −.01 | 51.2 | +3.7 | 80 | 13 | 61 | 25 | 17 | 41 | 38 | 46 | 41 | 74 | 2.90 | −1.5 | 10 | 4,900 | nw. | 30 | s. | 25 | 12 | 6 | 13 | 5.7 | 0.0 | 0.0 |
| Thomasville | 273 | 49 | 58 | 29.84 | 30.14 | −.01 | 57.8 | +5.3 | 80 | 13 | 68 | 30 | 30 | 48 | 32 | 51 | 47 | 77 | 1.27 | −2.4 | 7 | 4,062 | sw. | 22 | sw. | 23 | 8 | 9 | 14 | 6.0 | 0.0 | 0.0 |
| Apalachicola | 36 | 42 | 49 | 30.09 | 30.13 | ---- | 59.6 | ---- | 78 | 22 | 66 | 36 | 30 | 53 | 21 | 56 | 53 | 85 | 1.16 | ---- | 8 | 6,192 | e. | 30 | n. | 15 | 9 | 14 | 8 | 5.0 | 0.0 | 0.0 |
| Pensacola | 56 | 149 | 185 | 30.06 | 30.12 | −.03 | 58.2 | +4.2 | 72 | 9 | 65 | 33 | 30 | 52 | 28 | 55 | 51 | 81 | 1.35 | −2.8 | 7 | 10,521 | n. | 42 | sw. | 28 | 5 | 7 | 19 | 6.8 | 0.0 | 0.0 |
| Anniston | 741 | 9 | 57 | 29.36 | 30.17 | +.01 | 48.2 | +4.0 | 73 | 13 | 58 | 18 | 17 | 39 | 36 | ---- | ---- | ---- | 7.69 | +3.2 | 13 | 5,153 | nw. | 25 | w. | 25 | 10 | 9 | 12 | 5.5 | 0.0 | 0.0 |
| Birmingham | 700 | 11 | 48 | 29.38 | 30.16 | .00 | 49.4 | +3.0 | 73 | 13 | 58 | 20 | 16 | 40 | 36 | 44 | 40 | 76 | 10.61 | +6.0 | 14 | 6,146 | n. | 27 | s. | 25 | 9 | 10 | 12 | 5.7 | 0.0 | 0.0 |
| Mobile | 57 | 125 | 161 | 30.07 | 30.13 | −.02 | 57.7 | +5.5 | 78 | 13 | 66 | 31 | 16 | 50 | 31 | 53 | 49 | 79 | 1.65 | −2.9 | 9 | 8,432 | n. | 34 | sw. | 25 | 5 | 12 | 14 | 6.3 | 0.0 | 0.0 |
| Montgomery | 223 | 100 | 112 | 29.90 | 30.16 | .00 | 53.6 | +4.2 | 80 | 13 | 63 | 26 | 16 | 44 | 37 | 48 | 43 | 72 | 3.72 | −0.8 | 9 | 5,640 | nw. | 34 | w. | 28 | 10 | 7 | 14 | 5.8 | 0.0 | 0.0 |
| Corinth | 469 | 6 | ---- | ---- | ---- | ---- | 45.4 | ---- | 71 | 4 | 54 | 17 | 16 | 37 | 32 | ---- | ---- | ---- | 10.44 | ---- | 15 | ---- | s. | ---- | ---- | | 2 | 15 | 14 | ---- | T. | 0.0 |
| Meridian | 375 | 87 | 95 | 29.72 | 30.13 | −.03 | 52.6 | +4.9 | 76 | 9 | 62 | 21 | 16 | 43 | 36 | 47 | 44 | 78 | 7.90 | +2.7 | 14 | 4,828 | n. | 33 | w. | 25 | 7 | 5 | 19 | 6.8 | 0.0 | 0.0 |
| Vicksburg | 247 | 65 | 73 | 29.86 | 30.15 | .00 | 52.4 | +2.4 | 74 | 20 | 61 | 22 | 16 | 44 | 32 | 48 | 43 | 75 | 9.00 | +4.0 | 12 | 5,731 | n. | 31 | w. | 21 | 9 | 4 | 18 | 6.5 | 0.0 | 0.0 |
| New Orleans | 53 | 76 | 84 | 30.06 | 30.12 | −.01 | 61.0 | +5.4 | 82 | 23 | 69 | 35 | 16 | 53 | 28 | 56 | 52 | 78 | 2.18 | −2.3 | 11 | 5,218 | s. | 22 | nw. | 28 | 8 | 13 | 10 | 5.8 | 0.0 | 0.0 |
| ***West Gulf States*** | | | | | | | 51.3 | +0.9 | | | | | | | | | | 79 | 5.17 | +2.3 | | | | | | | | | | 6.4 | | |
| Shreveport | 249 | 77 | 93 | 29.85 | 30.13 | .00 | 51.2 | +2.1 | 77 | 12 | 60 | 22 | 16 | 43 | 30 | 47 | 44 | 80 | 9.20 | +4.8 | 12 | 5,159 | se. | 23 | s. | 3 | 10 | 4 | 17 | 6.3 | 0.0 | 0.0 |
| Bentonville | 1,303 | 11 | 44 | ---- | ---- | ---- | 38.4 | +0.9 | 68 | 12 | 47 | 7 | 15 | 30 | 39 | ---- | ---- | ---- | 2.96 | ---- | 9 | 4,880 | s. | 21 | s. | 11 | 12 | 6 | 13 | ---- | T. | 0.0 |
| Fort Smith | 457 | 79 | 94 | 29.62 | 30.11 | −.03 | 42.1 | 0.0 | 73 | 12 | 50 | 15 | 15 | 34 | 38 | 37 | 34 | 78 | 3.28 | +0.4 | 10 | 7,058 | e. | 34 | sw. | 12 | 13 | 3 | 15 | 5.6 | T. | 0.0 |
| Little Rock | 357 | 136 | 144 | 29.74 | 30.13 | −.01 | 43.6 | −0.6 | 72 | 12 | 52 | 20 | 15 | 36 | 37 | 40 | 35 | 75 | 9.46 | +5.2 | 12 | 6,521 | n. | 36 | nw. | 13 | 9 | 6 | 16 | 6.3 | 2.5 | 0.0 |
| Austin | 605 | 136 | 148 | 29.45 | 30.10 | ---- | 52.4 | +1.4 | 79 | 4 | 61 | 27 | 15 | 44 | 33 | ---- | ---- | ---- | 4.16 | ---- | 14 | 6,270 | n. | 30 | n. | 15 | 7 | 7 | 17 | 6.6 | 0.0 | 0.0 |
| Brownsville | 57 | 53 | 61 | 29.98 | 30.03 | ---- | 62.0 | +0.8 | 81 | 7 | 70 | 34 | 15 | 54 | 34 | 58 | 55 | 86 | 5.62 | ---- | 12 | 6,744 | s. | 30 | s. | 27 | 5 | 7 | 19 | 7.1 | 0.0 | 0.0 |
| Corpus Christi | 20 | 11 | 78 | 30.06 | 30.08 | −.04 | 59.1 | +1.1 | 79 | 8 | 66 | 31 | 15 | 52 | 31 | 56 | 53 | 83 | 1.74 | +0.4 | 14 | 7,887 | se. | 28 | n. | 13 | 6 | 5 | 20 | 7.4 | 0.0 | 0.0 |
| Dallas | 512 | 220 | 227 | 29.55 | 30.12 | ---- | 47.8 | ---- | 75 | 1 | 57 | 20 | 16 | 39 | 41 | ---- | ---- | ---- | 3.29 | ---- | 12 | 9,939 | se. | 48 | sw. | 12 | 14 | 3 | 14 | 5.0 | 6.4 | 0.0 |
| Fort Worth | 670 | 106 | 114 | 29.38 | 30.11 | −.01 | 47.8 | +0.3 | 77 | 1 | 57 | 18 | 16 | 39 | 33 | 41 | 36 | 71 | 3.03 | +1.2 | 12 | 6,530 | s. | 29 | sw. | 12 | 12 | 6 | 13 | 5.0 | 2.0 | 0.0 |
| Galveston | 54 | 106 | 114 | 30.05 | 30.11 | −.01 | 58.0 | +1.6 | 75 | 9 | 64 | 34 | 16 | 52 | 22 | 55 | 53 | 86 | 4.37 | +0.6 | 10 | 9,093 | n. | 40 | nw. | 25 | 7 | 11 | 13 | 6.3 | 0.0 | 0.0 |
| Groesbeck | 461 | 11 | 56 | 29.61 | 30.10 | ---- | 50.2 | ---- | 78 | 4 | 59 | 22 | 16 | 41 | 31 | ---- | ---- | ---- | 6.30 | ---- | 13 | 7,974 | n. | 38 | nw. | 25 | 9 | 4 | 18 | 6.5 | T. | 0.0 |
| Houston | 138 | 292 | 314 | 29.96 | 30.11 | ---- | 56.2 | +1.8 | 79 | 8 | 64 | 30 | 16 | 48 | 32 | ---- | ---- | ---- | 3.78 | ---- | 14 | 10,550 | e. | 39 | nw. | 25 | 6 | 7 | 18 | 7.0 | 0.0 | 0.0 |
| Palestine | 510 | 64 | 72 | 29.57 | 30.11 | −.01 | 51.2 | +1.3 | 80 | 12 | 60 | 22 | 16 | 42 | 34 | 46 | 41 | 75 | 8.73 | +5.1 | 14 | 6,048 | nw. | 23 | s. | 21 | 9 | 6 | 16 | 6.3 | T. | 0.0 |
| Port Arthur | 34 | 58 | 66 | 30.06 | 30.10 | ---- | 57.6 | ---- | 78 | 5 | 65 | 30 | 16 | 50 | 29 | ---- | ---- | ---- | 4.97 | ---- | 8 | 6,885 | s. | 30 | nw. | 25 | 7 | 5 | 19 | 6.7 | 0.0 | 0.0 |
| San Antonio | 693 | 119 | 132 | 29.35 | 30.08 | −.03 | 54.4 | +0.7 | 70 | 4 | 63 | 28 | 16 | 46 | 33 | 49 | 45 | 76 | 2.24 | +0.7 | 14 | 5,837 | ne. | 31 | nw. | 28 | 8 | 3 | 20 | 7.0 | 0.0 | 0.0 |
| Taylor | 583 | 55 | 63 | 29.51 | 30.13 | +.02 | 50.8 | +0.2 | 79 | 4 | 60 | 24 | 16 | 42 | 33 | ---- | ---- | ---- | 4.50 | +1.9 | 12 | 6,513 | n. | 27 | nw. | 15 | 8 | 9 | 14 | 5.9 | T. | 0.0 |

TABLE 1.—*Climatological data for Weather Bureau Stations, December, 1926*—Continued

| Districts and stations | Elevation of instruments: Barometer above sea level | Elevation of instruments: Thermometer above ground | Elevation of instruments: Anemometer above ground | Pressure: Station, reduced to mean of 24 hours | Pressure: Sea level, reduced to mean of 24 hours | Pressure: Departure from normal | Temperature of the air: Mean max. + mean min. ÷ 2 | Temperature: Departure from normal | Temperature: Maximum | Temperature: Date | Temperature: Mean maximum | Temperature: Minimum | Temperature: Date | Temperature: Mean minimum | Temperature: Greatest daily range | Mean wet thermometer | Mean temperature of the dew point | Mean relative humidity | Precipitation: Total | Precipitation: Departure from normal | Precipitation: Days with 0.01, or more | Wind: Total movement | Wind: Prevailing direction | Wind: Maximum velocity: Miles per hour | Wind: Maximum velocity: Direction | Wind: Maximum velocity: Date | Clear days | Partly cloudy days | Cloudy days | Average cloudiness, tenths | Total snowfall | Snow, sleet, and ice on ground at end of month |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ft. | Ft. | Ft. | In. | In. | In. | °F. | °F. | °F. | | °F. | °F. | | °F. | °F. | °F. | °F. | % | In. | In. | | Miles | | | | | | | | 0–10 | In. | In. |
| ***Ohio Valley and Tennessee*** | | | | | | | **35.5** | **−1.0** | | | | | | | | | | **79** | **5.38** | **+2.0** | | | | | | | | | | **7.6** | | |
| Chattanooga | 762 | 189 | 213 | 29.32 | 30.15 | −.01 | 44.4 | +1.1 | 71 | 13 | 52 | 19 | 16 | 36 | 30 | 39 | 34 | 71 | 10.54 | +6.2 | 14 | 6,031 | sw. | 37 | sw. | 25 | 5 | 11 | 15 | 6.5 | 0.0 | 0.0 |
| Knoxville | 995 | 102 | 111 | 29.05 | 30.13 | −.03 | 41.6 | +1.3 | 70 | 13 | 50 | 16 | 16 | 34 | 30 | 38 | 35 | 80 | 9.73 | +5.6 | 13 | 4,505 | ne. | 39 | w. | 25 | 7 | 10 | 14 | 6.6 | 0.4 | 0.0 |
| Memphis | 399 | 76 | 97 | 29.69 | 30.13 | −.02 | 43.1 | −0.5 | 71 | 4 | 50 | 20 | 14 | 36 | 38 | 40 | 36 | 77 | 9.50 | +5.1 | 12 | 6,273 | n. | 32 | nw. | 28 | 10 | 4 | 17 | 6.6 | 0.3 | 0.0 |
| Nashville | 546 | 168 | 191 | 29.56 | 30.16 | +.01 | 40.9 | −0.1 | 69 | 13 | 49 | 16 | 16 | 33 | 41 | 38 | 34 | 78 | 13.53 | +9.7 | 13 | 7,497 | nw. | 38 | nw. | 25 | 6 | 7 | 18 | 7.1 | T. | 0.0 |
| Lexington | 989 | 193 | 230 | 29.03 | 30.14 | .00 | 35.0 | −0.8 | 66 | 13 | 42 | 10 | 16 | 28 | 40 | | | | 4.32 | +1.0 | 12 | 10,204 | sw. | 38 | nw. | 5 | 3 | 9 | 19 | 7.5 | 0.2 | T. |
| Louisville | 525 | 188 | 234 | 29.55 | 30.15 | +.01 | 35.2 | −2.4 | 64 | 13 | 42 | 12 | 16 | 28 | 39 | 33 | 29 | 75 | 3.71 | 0.0 | 12 | 8,625 | nw. | 33 | w. | 13 | 4 | 6 | 21 | 7.5 | 0.1 | 0.0 |
| Evansville | 431 | 76 | 116 | 29.68 | 30.16 | +.03 | 35.2 | −1.9 | 64 | 3 | 42 | 11 | 15 | 28 | 39 | 33 | 29 | 79 | 2.63 | −1.2 | 12 | 6,703 | n. | 30 | w. | 13 | 5 | 6 | 20 | 7.6 | 1.5 | T. |
| Indianapolis | 822 | 194 | 230 | 29.21 | 30.13 | +.01 | 29.6 | −2.6 | 58 | 3 | 36 | 5 | 15 | 23 | 41 | 27 | 24 | 81 | 1.95 | −1.1 | 14 | 9,604 | nw. | 38 | w. | 13 | 5 | 4 | 22 | 8.0 | 9.2 | 3.5 |
| Royal Center | 736 | 11 | 55 | 29.29 | 30.12 | | 26.2 | | 55 | 13 | 34 | 0 | 15 | 19 | 47 | | | | 1.22 | | 10 | 8,771 | w. | 36 | e. | 4 | 6 | 4 | 21 | 7.6 | 6.6 | 4.2 |
| Terre Haute | 575 | 96 | 129 | 29.49 | 30.13 | | 30.3 | | 60 | 3 | 37 | 3 | 15 | 23 | 43 | 28 | 25 | 82 | 1.42 | | 13 | 7,776 | nw. | 31 | w. | 13 | 5 | 5 | 21 | 7.8 | 7.6 | 4.6 |
| Cincinnati | 627 | 11 | 51 | 29.43 | 30.14 | +.01 | 32.0 | −1.4 | 65 | 13 | 39 | 9 | 18 | 25 | 42 | 30 | 27 | 82 | 2.47 | −0.5 | 14 | 6,321 | sw. | 26 | w. | 13 | 6 | 3 | 22 | 7.6 | 6.4 | 3.2 |
| Columbus | 822 | 179 | 222 | 29.21 | 30.12 | .00 | 30.4 | −2.0 | 63 | 13 | 37 | 8 | 18 | 24 | 37 | 28 | 26 | 84 | 3.05 | +0.3 | 16 | 8,289 | s. | 37 | nw. | 26 | 5 | 4 | 22 | 8.1 | 3.4 | 2.1 |
| Dayton | 899 | 137 | 173 | 29.14 | 30.13 | | 30.6 | −2.0 | 63 | 13 | 37 | 8 | 18 | 24 | 40 | 28 | 25 | 81 | 2.30 | −0.3 | 19 | 7,487 | sw. | 35 | nw. | 13 | 3 | 6 | 22 | 7.9 | 5.3 | 3.2 |
| Elkins | 1,947 | 59 | 67 | 28.00 | 30.14 | +.02 | 32.9 | +0.2 | 63 | 13 | 42 | −4 | 18 | 24 | 37 | 29 | 27 | 83 | 5.56 | +2.1 | 23 | 4,559 | w. | 31 | w. | 26 | 2 | 4 | 25 | 8.5 | 4.6 | 0.8 |
| Parkersburg | 637 | 77 | 82 | 29.47 | 30.14 | .00 | 34.9 | −0.3 | 67 | 13 | 42 | 8 | 18 | 28 | 29 | 31 | 27 | 77 | 2.97 | +0.2 | 18 | 4,722 | se. | 28 | w. | 26 | 4 | 3 | 24 | 8.3 | 0.5 | 0.0 |
| Pittsburgh | 842 | 353 | 410 | 29.18 | 30.12 | +.01 | 31.6 | −2.6 | 60 | 13 | 38 | 7 | 18 | 25 | 26 | 29 | 26 | 82 | 3.12 | +0.4 | 17 | 8,787 | sw. | 48 | sw. | 26 | 2 | 4 | 25 | 8.6 | 4.4 | 0.9 |
| ***Lower Lake Region*** | | | | | | | **25.1** | **−4.0** | | | | | | | | | | **78** | **2.26** | **−0.6** | | | | | | | | | | **8.2** | | |
| Buffalo | 767 | 247 | 280 | 29.22 | 30.08 | +.02 | 25.2 | −4.6 | 51 | 13 | 31 | 5 | 5 | 19 | 25 | 24 | 21 | 83 | 4.62 | +1.2 | 21 | 13,139 | sw. | 66 | sw. | 16 | 1 | 8 | 22 | 8.5 | 40.6 | 8.0 |
| Canton | 448 | 10 | 61 | 29.58 | 30.08 | | 15.8 | −6.9 | 44 | 14 | 25 | −19 | 5 | 7 | 31 | | | | 2.15 | −1.4 | 18 | 6,529 | sw. | 39 | sw. | 14 | 7 | 2 | 22 | 7.5 | 22.6 | 8.0 |
| Oswego | 335 | 76 | 91 | | 30.10 | +.04 | 23.6 | −5.4 | 44 | 13 | 30 | 1 | 5 | 17 | 28 | | | 83 | 1.12 | −2.5 | 20 | 8,590 | sw. | 30 | sw. | 14 | 1 | 3 | 27 | | 25.4 | 5.5 |
| Rochester | 523 | 86 | 102 | 29.50 | 30.10 | +.04 | 25.0 | −4.3 | 49 | 13 | 31 | 3 | 5 | 19 | 28 | 23 | 18 | 75 | 2.87 | 0.0 | 20 | 6,580 | w. | 30 | w. | 14 | 0 | 7 | 24 | 9.0 | 28.5 | 6.5 |
| Syracuse | 597 | 97 | 113 | 29.44 | 30.11 | +.04 | 24.0 | −4.3 | 47 | 14 | 31 | 0 | 5 | 18 | 29 | | | | 2.84 | +0.2 | 16 | 7,634 | s. | 38 | nw. | 1 | 1 | 7 | 23 | 8.1 | 25.7 | 6.5 |
| Erie | 714 | 130 | 166 | 29.29 | 30.09 | +.02 | 27.4 | −4.5 | 56 | 13 | 33 | 6 | 19 | 21 | 31 | 25 | 20 | 72 | 2.57 | −0.5 | 16 | 12,390 | s. | 46 | sw. | 16 | 1 | 2 | 28 | 9.0 | 22.3 | 6.8 |
| Cleveland | 762 | 190 | 201 | 29.26 | 30.11 | +.02 | 28.0 | −3.2 | 58 | 13 | 34 | 7 | 18 | 22 | 30 | 26 | 22 | 80 | 2.01 | −0.6 | 12 | 11,506 | s. | 60 | n. | 26 | 1 | 4 | 26 | 8.9 | 14.2 | 6.3 |
| Sandusky | 629 | 62 | 70 | 29.41 | 30.12 | +.03 | 27.8 | −3.4 | 59 | 13 | 34 | 8 | 15 | 22 | 36 | | | | 1.63 | −0.7 | 12 | 7,282 | sw. | 42 | n. | 26 | 2 | 8 | 21 | 8.2 | 12.6 | 8.2 |
| Toledo | 628 | 208 | 243 | 29.41 | 30.12 | +.04 | 26.8 | −3.6 | 58 | 13 | 34 | 4 | 18 | 20 | 37 | 25 | 21 | 76 | 1.30 | −0.9 | 12 | 10,842 | sw. | 46 | w. | 13 | 7 | 5 | 19 | 7.4 | 9.1 | 3.0 |
| Fort Wayne | 856 | 113 | 124 | 29.15 | 30.10 | | 26.8 | −0.5 | 56 | 13 | 34 | 2 | 18 | 20 | 42 | 25 | 21 | 81 | 1.30 | | 14 | 7,556 | sw. | 30 | ne. | 4 | 6 | 4 | 21 | 7.6 | 6.8 | 3.5 |
| Detroit | 730 | 218 | 258 | 29.29 | 30.11 | +.04 | 25.9 | −3.4 | 48 | 13 | 32 | 5 | 18 | 20 | 27 | 24 | 20 | 77 | 1.39 | −1.0 | 16 | 9,062 | sw. | 38 | sw. | 16 | 4 | 4 | 23 | 8.2 | 10.0 | 0.0 |
| ***Upper Lake Region*** | | | | | | | **20.7** | **−4.0** | | | | | | | | | | **85** | **1.79** | **−0.3** | | | | | | | | | | **7.8** | | |
| Alpena | 609 | 13 | 92 | 29.38 | 30.07 | +.05 | 21.7 | −3.1 | 40 | 13 | 28 | −8 | 18 | 16 | 24 | 20 | 17 | 83 | 1.95 | −0.3 | 15 | 9,226 | sw. | 44 | nw. | 1 | 4 | 3 | 24 | 8.3 | 23.1 | 4.1 |
| Escanaba | 612 | 54 | 60 | 29.37 | 30.07 | +.04 | 18.0 | −4.4 | 36 | 13 | 25 | −17 | 15 | 11 | 31 | 17 | 15 | 88 | 2.49 | +0.8 | 13 | 7,540 | sw. | 36 | n. | 3 | 6 | 8 | 17 | 6.6 | 18.0 | 10.5 |
| Grand Haven | 632 | 54 | 89 | 29.38 | 30.10 | +.05 | 24.6 | −4.7 | 48 | 13 | 31 | −8 | 18 | 18 | 35 | 23 | 21 | 86 | 1.32 | −1.2 | 13 | 9,765 | se. | 44 | w. | 11 | 2 | 5 | 24 | 8.6 | 7.1 | T. |
| Grand Rapids | 707 | 70 | 87 | 29.30 | 30.10 | +.05 | 25.0 | −3.5 | 47 | 13 | 31 | −5 | 18 | 19 | 31 | 22 | 19 | 80 | 1.86 | −0.7 | 10 | 5,209 | se. | 25 | w. | 1 | 1 | 5 | 25 | 8.6 | 13.3 | T. |
| Houghton | 668 | 62 | 99 | 29.27 | 30.03 | +.01 | 17.2 | −4.6 | 36 | 23 | 24 | −14 | 18 | 10 | 34 | | | | 3.41 | +0.9 | 19 | 7,034 | e. | 44 | w. | 13 | 6 | 0 | 25 | 8.3 | 33.1 | 17.2 |
| Lansing | 878 | 11 | 62 | 29.12 | 30.10 | | 22.6 | −4.6 | 46 | 13 | 30 | −14 | 18 | 15 | 32 | 21 | 20 | 92 | 1.58 | −0.5 | 17 | 5,583 | sw. | 27 | nw. | 1 | 6 | 8 | 17 | 7.3 | 13.0 | 0.4 |
| Ludington | 637 | 60 | 66 | 29.35 | 30.07 | | 23.4 | | 44 | 13 | 29 | −4 | 18 | 18 | 34 | 22 | 20 | 85 | 1.93 | | 18 | 9,450 | se. | 44 | w. | 15 | 2 | 3 | 26 | 8.7 | 16.7 | 2.4 |
| Marquette | 734 | 77 | 111 | 29.20 | 30.04 | +.02 | 19.1 | −3.5 | 36 | 12 | 26 | −16 | 15 | 13 | 25 | 17 | 15 | 85 | 2.36 | −0.2 | 19 | 8,122 | w. | 39 | sw. | 7 | 5 | 3 | 23 | 8.1 | 21.0 | 16.2 |
| Port Huron | 638 | 70 | 120 | 29.37 | 30.09 | +.03 | 25.0 | −2.6 | 48 | 13 | 31 | 5 | 18 | 19 | 25 | 23 | 21 | 86 | 1.17 | −1.0 | 10 | 9,438 | nw. | 42 | nw. | 1 | 2 | 6 | 23 | 8.4 | 11.8 | 0.8 |
| Saginaw | 641 | | | | | | 22.4 | −4.8 | 46 | 13 | 29 | −5 | 18 | 16 | 31 | | | | 1.52 | | 14 | | w. | | | | 7 | 4 | 20 | | 8.7 | |
| Sault Sainte Marie | 614 | 11 | 52 | 29.34 | 30.08 | +.02 | 16.1 | −4.4 | 36 | 13 | 23 | −14 | 17 | 9 | 28 | 16 | 14 | 88 | 2.15 | −0.2 | 17 | 6,821 | se. | 35 | w. | 14 | 4 | 2 | 25 | 8.3 | 20.4 | 10.3 |
| Chicago | 673 | 7 | 131 | 29.35 | 30.10 | +.02 | 26.6 | −2.2 | 51 | 13 | 33 | −3 | 15 | 20 | 46 | 24 | 20 | 75 | 0.87 | −1.2 | 8 | 9,515 | nw. | 30 | w. | 13 | 8 | 6 | 17 | 6.8 | 5.5 | T. |
| Green Bay | 617 | 109 | 141 | 29.38 | 30.08 | +.04 | 17.7 | −4.6 | 38 | 13 | 25 | −17 | 15 | 10 | 43 | 17 | 15 | 88 | 1.67 | −0.1 | 11 | 8,584 | sw. | 44 | w. | 13 | 5 | 11 | 15 | 6.7 | 15.2 | 3.3 |
| Milwaukee | 681 | 125 | 139 | 29.32 | 30.09 | +.03 | 23.3 | −2.8 | 42 | 13 | 30 | −8 | 14 | 16 | 44 | 21 | 17 | 76 | 1.23 | −0.7 | 9 | 8,413 | w. | 42 | e. | 4 | 6 | 6 | 19 | 7.1 | 8.8 | T. |
| Duluth | 1,133 | 5 | 47 | 28.77 | 30.06 | +.01 | 10.1 | −5.8 | 35 | 30 | 18 | −25 | 14 | 2 | 31 | 9 | 8 | 94 | 1.25 | 0.0 | 9 | 9,802 | sw. | 51 | nw. | 13 | 6 | 7 | 18 | 7.1 | 13.3 | 12.0 |
| ***North Dakota*** | | | | | | | **9.4** | **−2.6** | | | | | | | | | | **84** | **0.67** | **0.0** | | | | | | | | | | **5.9** | | |
| Moorhead | 940 | 50 | 58 | 29.01 | 30.08 | .00 | 9.0 | −2.5 | 36 | 30 | 19 | −22 | 14 | −1 | 44 | 9 | 8 | 89 | 0.79 | 0.0 | 8 | 7,548 | s. | 32 | nw. | 30 | 3 | 7 | 21 | 7.7 | 8.2 | 8.3 |
| Bismarck | 1,674 | 8 | 57 | 28.20 | 30.08 | .00 | 11.4 | −3.3 | 45 | 11 | 21 | −18 | 14 | 2 | 47 | 10 | 7 | 84 | 0.64 | 0.0 | 3 | 7,254 | nw. | 40 | nw. | 12 | 11 | 14 | 6 | 4.4 | 5.2 | 0.4 |
| Devils Lake | 1,478 | 11 | 44 | 28.37 | 30.04 | −.02 | 6.8 | −1.2 | 35 | 30 | 16 | −25 | 14 | −2 | 47 | 5 | 3 | 86 | 0.43 | 0.0 | 5 | 8,293 | w. | 36 | nw. | 10 | 9 | 7 | 15 | 6.3 | 6.1 | 3.0 |
| Ellendale | 1,457 | 10 | 56 | 28.45 | 30.08 | | 11.6 | | 41 | 11 | 22 | −16 | 13 | 1 | 42 | | | | 0.55 | | 4 | 10,955 | nw. | 45 | nw. | 30 | 6 | 11 | 14 | 6.6 | 5.8 | 1.8 |
| Grand Forks | 833 | 12 | 67 | | | | 7.0 | | 36 | 30 | 17 | −25 | 14 | −3 | 41 | | | | 0.37 | | 8 | | s. | 39 | se. | 11 | 6 | 8 | 17 | | 6.5 | 8.9 |
| Williston | 1,878 | 41 | 48 | 27.98 | 30.06 | .00 | 10.3 | −3.5 | 41 | 11 | 20 | −19 | 14 | 1 | 32 | 9 | 5 | 78 | 0.81 | +0.2 | 6 | 5,902 | w. | 31 | w. | 29 | 14 | 8 | 9 | 4.5 | 8.5 | 4.0 |
| ***Upper Mississippi Valley*** | | | | | | | **24.2** | **−2.6** | | | | | | | | | | **82** | **1.48** | **−0.3** | | | | | | | | | | **7.0** | | |
| Minneapolis | 918 | 102 | 208 | 29.04 | 30.07 | | 15.0 | −4.6 | 39 | 30 | 22 | −18 | 14 | 8 | 27 | | | | 1.48 | +0.5 | 9 | 8,871 | se. | 39 | nw. | 30 | 4 | 8 | 19 | 7.5 | 12.3 | 7.5 |
| St. Paul | 837 | 236 | 261 | 29.14 | 30.10 | +.02 | 13.8 | −5.2 | 38 | 30 | 22 | −18 | 14 | 6 | 29 | | | | 1.73 | +0.7 | 11 | 9,158 | se. | 42 | sw. | 30 | 5 | 12 | 14 | 7.1 | 17.2 | 9.5 |
| La Crosse | 714 | 11 | 48 | 29.30 | 30.11 | +.03 | 17.8 | −4.5 | 42 | 30 | 26 | −15 | 14 | 9 | 46 | | | | 1.64 | +0.3 | 7 | 3,981 | se. | 19 | w. | 13 | 6 | 5 | 20 | 7.3 | 12.1 | 5.5 |
| Madison | 974 | 70 | 78 | 29.01 | 30.12 | +.04 | 19.1 | −3.7 | 38 | 20 | 26 | −14 | 14 | 12 | 43 | 18 | 16 | 88 | 1.82 | 0.0 | 9 | 7,339 | nw. | 35 | ne. | 4 | 8 | 8 | 15 | 6.5 | 9.8 | 2.4 |
| Wausau | 1,247 | 4 | | 28.68 | 30.08 | | 14.2 | | 34 | 12 | 22 | −20 | 14 | 6 | 41 | | | | 1.16 | | 11 | | n. | | | | 7 | 5 | 19 | 7.3 | 14.9 | 11.0 |
| Charles City | 1,015 | 10 | 49 | 28.99 | 30.12 | +.02 | 16.9 | −3.5 | 39 | 3 | 25 | −15 | 14 | 9 | 31 | 16 | 14 | 89 | 1.84 | +0.6 | 6 | 5,393 | se. | 25 | nw. | 13 | 6 | 9 | 16 | 6.7 | 10.5 | 4.7 |
| Davenport | 606 | 71 | 79 | 29.44 | 30.14 | +.04 | 25.0 | −2.1 | 46 | 30 | 32 | −5 | 14 | 18 | 41 | 23 | 21 | 85 | 0.65 | −1.0 | 5 | 5,758 | w. | 26 | w. | 13 | 7 | 5 | 19 | 6.7 | 0.2 | 0.0 |
| Des Moines | 861 | 84 | 97 | 29.18 | 30.12 | +.01 | 24.4 | −1.6 | 48 | 20 | 32 | −5 | 14 | 17 | 27 | 22 | 19 | 80 | 0.67 | −0.6 | 6 | 5,417 | nw. | 26 | sw. | 19 | 5 | 6 | 20 | 7.2 | 1.0 | T. |
| Dubuque | 700 | 81 | 96 | 29.32 | 30.11 | +.01 | 22.0 | −2.7 | 41 | 30 | 29 | −10 | 14 | 15 | 43 | 20 | 16 | 80 | 0.99 | −0.7 | 5 | 5,225 | nw. | 22 | n. | 1 | 6 | 8 | 17 | 7.0 | 4.8 | 0.4 |
| Keokuk | 614 | 64 | 78 | 29.44 | 30.15 | +.03 | 27.8 | −1.8 | 55 | 3 | 36 | −2 | 14 | 20 | 42 | 25 | 21 | 76 | 1.45 | −0.4 | 5 | 6,023 | n. | 30 | w. | 13 | 6 | 8 | 17 | 7.0 | 5.7 | 0.2 |
| Cairo | 358 | 87 | 93 | 29.75 | 30.14 | +.03 | 37.2 | −0.6 | 65 | 3 | 44 | 12 | 15 | 30 | 41 | 34 | 31 | 79 | 4.15 | +0.8 | 11 | 7,466 | s. | 31 | n. | 25 | 7 | 5 | 19 | 7.2 | 1.2 | 0.0 |
| Peoria | 609 | 11 | 45 | 29.45 | 30.14 | +.03 | 26.8 | −1.3 | 52 | 12 | 34 | −2 | 14 | 20 | 46 | 25 | 22 | 82 | 1.12 | −1.2 | 7 | 5,730 | se. | 25 | w. | 13 | 4 | 8 | 19 | 7.1 | 1.6 | 0.0 |
| Springfield, Ill. | 636 | 10 | 91 | 29.43 | 30.13 | +.01 | 29.6 | −2.1 | 58 | 3 | 36 | 2 | 14 | 23 | 45 | 27 | 24 | 80 | 0.90 | −1.5 | 7 | 6,920 | w. | 26 | w. | 13 | 6 | 7 | 18 | 6.9 | 1.7 | 0.0 |
| Hannibal | 534 | 74 | 109 | 29.56 | 30.15 | +.03 | 30.6 | −0.9 | 63 | 12 | 38 | 2 | 14 | 23 | 38 | | | | 1.07 | −0.6 | 5 | 6,816 | nw. | 26 | nw. | 13 | 7 | 7 | 17 | 6.6 | 1.0 | 0.0 |
| St. Louis | 568 | 265 | 303 | 29.51 | 30.14 | +.01 | 33.4 | −1.3 | 67 | 3 | 41 | 6 | 15 | 26 | 45 | 30 | 26 | 77 | 1.15 | −1.1 | 8 | 9,368 | nw. | 39 | sw. | 11 | 11 | 1 | 19 | 6.7 | 2.0 | T. |
| ***Missouri Valley*** | | | | | | | **26.8** | **−0.9** | | | | | | | | | | **81** | **1.01** | **−0.1** | | | | | | | | | | **5.9** | | |
| Columbia, Mo. | 784 | 11 | 84 | 29.28 | 30.14 | +.02 | 32.2 | −1.0 | 64 | 3 | 40 | 3 | 15 | 25 | 38 | | | | 1.60 | −0.4 | 7 | 6,491 | nw. | 28 | nw. | 13 | 10 | 5 | 16 | 6.4 | 1.0 | 0.0 |
| Kansas City | 963 | 161 | 181 | 29.06 | 30.13 | +.01 | 31.7 | −0.8 | 62 | 3 | 39 | 0 | 14 | 24 | 32 | 28 | 25 | 77 | 0.96 | −0.4 | 6 | 8,353 | nw. | 39 | nw. | 13 | 11 | 6 | 14 | 5.9 | T. | 0.0 |
| St. Joseph | 967 | 11 | 49 | 29.05 | 30.12 | | 29.6 | | 62 | 3 | 37 | −1 | 14 | 22 | 27 | 26 | 24 | 82 | 0.86 | | 6 | 6,174 | nw. | 33 | nw. | 13 | 14 | 4 | 13 | 5.6 | 1.3 | 0.0 |
| Springfield, Mo. | 1,324 | 98 | 104 | 28.67 | 30.11 | −.02 | 35.4 | −0.8 | 67 | 3 | 43 | 4 | 15 | 28 | 42 | 32 | 29 | 82 | 1.92 | −0.8 | 9 | 8,442 | nw. | 32 | se. | 6 | 12 | 3 | 16 | 5.8 | T. | 0.0 |
| Iola | 984 | 11 | 50 | 29.04 | 30.14 | +.02 | 33.2 | −0.7 | 65 | 3 | 42 | 2 | 15 | 25 | 40 | | | | 1.56 | +0.5 | 8 | 5,174 | n. | 25 | s. | 19 | 12 | 4 | 15 | 6.1 | 1.5 | 0.0 |
| Topeka | 987 | 92 | 107 | | | | 31.0 | −1.0 | 62 | 3 | 39 | −1 | 14 | 23 | 32 | | | | 0.97 | +0.1 | 6 | 6,780 | sw. | 34 | n. | 12 | 13 | 7 | 11 | 4.9 | 1.0 | 0.0 |
| Lincoln | 1,189 | 11 | 84 | 28.81 | 30.13 | +.01 | 26.0 | −1.6 | 47 | 30 | 33 | −5 | 14 | 19 | 34 | 24 | 22 | 81 | 0.93 | +0.3 | 8 | 6,960 | s. | 39 | n. | 12 | 5 | 8 | 18 | 7.2 | 6.2 | T. |
| Omaha | 1,105 | 115 | 122 | 28.90 | 30.14 | +.03 | 25.1 | −1.3 | 46 | 19 | 32 | −6 | 14 | 18 | 30 | 23 | 20 | 82 | 1.20 | +0.3 | 6 | 6,071 | nw. | 38 | n. | 12 | 8 | 10 | 13 | 6.1 | 6.2 | 1.5 |
| Valentine | 2,598 | 47 | 54 | 27.28 | 30.11 | +.01 | 24.1 | −0.5 | 58 | 2 | 36 | −16 | 15 | 13 | 45 | 20 | 17 | 79 | 0.45 | −0.2 | 3 | 6,751 | w. | 39 | n. | 12 | 11 | 13 | 7 | 4.4 | 7.2 | 0.0 |
| Sioux City | 1,135 | 94 | 164 | 28.87 | 30.14 | +.02 | 21.0 | −2.1 | 45 | 30 | 28 | −11 | 14 | 14 | 28 | 20 | 17 | 86 | 1.14 | +0.4 | 6 | 8,583 | nw. | 44 | nw. | 13 | 6 | 9 | 16 | 6.6 | 9.6 | 0.9 |
| Huron | 1,306 | 59 | 74 | 28.66 | 30.12 | +.02 | 18.2 | −0.5 | 55 | 11 | 28 | −13 | 15 | 9 | 41 | 16 | 13 | 84 | 0.28 | −0.3 | 3 | 7,401 | s. | 42 | nw. | 12 | 7 | 13 | 11 | 5.7 | 2.3 | 0.0 |
| Pierre | 1,572 | 70 | 75 | | 30.12 | +.02 | 22.4 | +0.6 | 58 | 11 | 33 | −9 | 15 | 12 | 45 | | | 80 | 0.23 | −0.3 | 2 | 6,487 | nw. | 42 | nw. | 12 | 13 | 8 | 10 | | 2.5 | 0.0 |
| Yankton | 1,233 | 49 | 57 | 28.74 | 30.12 | +.01 | 21.6 | −1.2 | 49 | 30 | 30 | −9 | 13 | 14 | 33 | | | | 0.85 | +0.1 | 6 | 5,817 | nw. | 36 | nw. | 12 | 4 | 13 | 14 | 6.6 | 6.5 | T |

TABLE 1.—*Climatological data for Weather Bureau Stations, December, 1926*—Continued

| Districts and stations | Elevation of instruments: Barometer above sea level | Elevation of instruments: Thermometer above ground | Elevation of instruments: Anemometer above ground | Pressure: Station, reduced to mean of 24 hours | Pressure: Sea level, reduced to mean of 24 hours | Pressure: Departure from normal | Temperature of the air: Mean max. + mean min. ÷ 2 | Temperature: Departure from normal | Temperature: Maximum | Temperature: Date | Temperature: Mean maximum | Temperature: Minimum | Temperature: Date | Temperature: Mean minimum | Temperature: Greatest daily range | Mean wet thermometer | Mean temperature of the dew point | Mean relative humidity | Precipitation: Total | Precipitation: Departure from normal | Precipitation: Days with 0.01, or more | Wind: Total movement | Wind: Prevailing direction | Wind: Maximum velocity: Miles per hour | Wind: Maximum velocity: Direction | Wind: Maximum velocity: Date | Clear days | Partly cloudy days | Cloudy days | Average cloudiness, tenths | Total snowfall | Snow, sleet, and ice on ground at end of month |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Ft.* | *Ft.* | *Ft.* | *In.* | *In.* | *In.* | *° F.* | *° F.* | *° F.* | | *° F.* | *° F.* | | *° F.* | *° F.* | *° F.* | *° F.* | *%* | *In.* | *In.* | | *Miles* | | | | | | | | *0-10* | *In.* | *In.* |
| ***Northern Slope*** | | | | | | | **21.9** | **−1.9** | | | | | | | | | | **76** | **0.64** | **−0.2** | | | | | | | | | | **5.8** | | |
| Billings | 3,140 | 5 | ---- | ---- | ---- | ---- | 24.3 | ---- | 60 | 2 | 36 | −24 | 14 | 12 | 36 | ---- | ---- | ---- | 0.55 | ---- | 6 | ---- | sw. | ---- | ---- | ---- | 20 | 4 | 7 | ---- | ---- | ---- |
| Havre | 2,505 | 11 | 44 | 27.32 | 30.08 | +.03 | 16.2 | −4.2 | 54 | 31 | 25 | −18 | 15 | 7 | 43 | 14 | 11 | 80 | 0.40 | −0.2 | 4 | 7,175 | sw. | 39 | sw. | 10 | 7 | 14 | 10 | 5.7 | 5.3 | 0.2 |
| Helena | 4,110 | 87 | 112 | 25.77 | 30.10 | −.03 | 24.7 | +0.5 | 57 | 2 | 32 | −20 | 14 | 17 | 49 | 22 | 18 | 74 | 0.50 | −0.3 | 5 | 5,187 | sw. | 45 | sw. | 19 | 2 | 7 | 22 | 7.9 | 3.8 | 0.0 |
| Kalispell | 2,973 | 48 | 56 | 26.94 | 30.11 | +.04 | 23.4 | −1.5 | 52 | 2 | 30 | −10 | 14 | 17 | 36 | 22 | 20 | 85 | 1.48 | −0.4 | 12 | 2,943 | nw. | 36 | ne. | 11 | 3 | 7 | 21 | 7.6 | 12.4 | 5.7 |
| Miles City | 2,371 | 48 | 55 | 27.48 | 30.15 | +.05 | 16.4 | −4.6 | 51 | 11 | 27 | −18 | 15 | 6 | 38 | 14 | 11 | 82 | 0.63 | 0.0 | 5 | 4,000 | s. | 36 | nw. | 11 | 14 | 6 | 11 | 4.7 | 7.4 | 4.5 |
| Rapid City | 3,250 | 50 | 58 | 26.57 | 30.13 | +.04 | 26.6 | −0.8 | 62 | 31 | 38 | −15 | 14 | 15 | 42 | 22 | 18 | 76 | 0.07 | −0.4 | 2 | 4,498 | nw. | 36 | nw. | 12 | 15 | 7 | 9 | 4.5 | 0.4 | 0.0 |
| Cheyenne | 6,088 | 84 | 101 | 23.91 | 30.07 | −.02 | 26.6 | −1.9 | 62 | 2 | 36 | −16 | 14 | 17 | 46 | 20 | 13 | 61 | 0.77 | +0.5 | 6 | 10,226 | w. | 62 | nw. | 11 | 12 | 3 | 16 | 5.8 | 9.0 | T. |
| Lander | 5,372 | 60 | 68 | 24.59 | 30.17 | +.02 | 18.5 | −1.9 | 58 | 2 | 30 | −26 | 14 | 7 | 34 | 14 | 9 | 72 | 0.86 | +0.2 | 3 | 2,363 | sw. | 28 | nw. | 11 | 16 | 10 | 5 | 4.4 | 9.5 | 2.0 |
| Sheridan | 3,790 | 10 | 47 | 26.05 | 30.11 | ---- | 21.0 | ---- | 56 | 11 | 34 | −17 | 14 | 8 | 43 | 17 | 12 | 73 | 0.49 | ---- | 9 | 2,808 | nw. | 30 | sw. | 11 | 9 | 12 | 10 | 5.0 | 5.6 | 0.6 |
| Yellowstone Park | 6,241 | 11 | 48 | 23.83 | 30.19 | +.03 | 18.1 | −3.5 | 46 | 2 | 25 | −26 | 14 | 11 | 26 | 17 | 13 | 78 | 0.83 | −1.0 | 16 | 6,525 | s. | 33 | sw. | 24 | 5 | 9 | 17 | 7.1 | 6.0 | 2.2 |
| North Platte | 2,821 | 11 | 51 | 27.10 | 30.15 | +.05 | 26.8 | +0.1 | 66 | 2 | 38 | −11 | 14 | 16 | 41 | 22 | 18 | 78 | 0.28 | −0.2 | 5 | 4,781 | w. | 30 | n. | 12 | 11 | 6 | 14 | 5.4 | 2.8 | 0.0 |
| ***Middle Slope*** | | | | | | | **32.4** | **−1.1** | | | | | | | | | | **75** | **0.28** | **+0.5** | | | | | | | | | | **4.9** | | |
| Denver | 5,292 | 106 | 113 | 24.67 | 30.08 | .00 | 29.8 | −2.5 | 68 | 2 | 41 | −11 | 14 | 19 | 45 | 24 | 17 | 66 | 1.04 | +0.4 | 6 | 5,074 | s. | 36 | n. | 12 | 14 | 9 | 8 | 4.3 | 14.8 | 0.3 |
| Pueblo | 4,685 | 80 | 86 | 25.25 | 30.06 | −.02 | 29.8 | −1.7 | 72 | 2 | 43 | −11 | 15 | 17 | 51 | 24 | 18 | 65 | 0.72 | +0.3 | 5 | 3,818 | nw. | 40 | w. | 11 | 17 | 7 | 7 | 4.5 | 6.0 | 0.0 |
| Concordia | 1,392 | 50 | 58 | 28.60 | 30.13 | +.02 | 30.0 | −0.7 | 52 | 3 | 37 | −1 | 14 | 22 | 34 | 26 | 23 | 80 | 0.53 | 0.0 | 6 | 5,383 | sw. | 28 | nw. | 13 | 11 | 10 | 10 | 5.4 | 1.5 | 0.0 |
| Dodge City | 2,509 | 11 | 51 | 27.45 | 30.15 | +.05 | 31.4 | −1.2 | 68 | 3 | 42 | −3 | 15 | 21 | 41 | 26 | 23 | 80 | 0.48 | −0.1 | 6 | 6,540 | nw. | 31 | s. | 18 | 19 | 3 | 9 | 4.1 | 2.2 | 0.0 |
| Wichita | 1,358 | 139 | 158 | 28.63 | 30.11 | .00 | 34.0 | −0.6 | 63 | 3 | 42 | 1 | 14 | 26 | 32 | 30 | 26 | 77 | 1.11 | +0.3 | 8 | 8,844 | s. | 36 | n. | 12 | 12 | 9 | 10 | 5.1 | 0.7 | 0.0 |
| Broken Arrow | 765 | 11 | 56 | 29.28 | 30.12 | ---- | 38.3 | ---- | 69 | 3 | 47 | 8 | 15 | 30 | 34 | ---- | ---- | ---- | 2.88 | ---- | 8 | 9,735 | n. | 39 | nw. | 12 | 12 | 3 | 16 | 5.7 | T. | 0.0 |
| Oklahoma City | 1,214 | 10 | 47 | 28.80 | 30.12 | +.01 | 39.2 | −0.1 | 73 | 3 | 48 | 6 | 15 | 30 | 40 | 35 | 32 | 81 | 3.79 | +2.0 | 7 | 7,666 | s. | 35 | n. | 12 | 14 | 5 | 12 | 5.1 | T. | 0.0 |
| ***Southern Slope*** | | | | | | | **43.6** | **−0.5** | | | | | | | | | | **72** | **2.52** | **+1.7** | | | | | | | | | | **5.3** | | |
| Abilene | 1,738 | 10 | 52 | 28.26 | 30.10 | −.01 | 45.8 | −0.2 | 78 | 1 | 56 | 15 | 15 | 36 | 35 | 39 | 35 | 73 | 6.69 | +5.6 | 8 | 7,108 | s. | 36 | w. | 12 | 12 | 6 | 13 | 5.3 | 2.0 | 0.0 |
| Amarillo | 3,676 | 10 | 49 | 26.27 | 30.09 | .00 | 37.0 | 0.0 | 76 | 2 | 48 | 10 | 15 | 26 | 45 | 31 | 25 | 70 | 0.96 | +0.1 | 6 | 5,771 | sw. | 36 | w. | 12 | 18 | 5 | 8 | 4.3 | 3.1 | 0.0 |
| Del Rio | 944 | 64 | 71 | 29.07 | 30.08 | −.02 | 52.3 | +0.1 | 77 | 5 | 60 | 29 | 30 | 44 | 32 | ---- | ---- | ---- | 1.33 | +0.4 | 10 | 6,590 | se. | 31 | nw. | 27 | 9 | 1 | 21 | 6.7 | 0.0 | 0.0 |
| Roswell | 3,566 | 75 | 85 | 26.38 | 30.06 | −.01 | 39.2 | −2.0 | 71 | 4 | 51 | 2 | 25 | 28 | 38 | 33 | 28 | 73 | 1.09 | +0.6 | 6 | 4,259 | s. | 29 | sw. | 22 | 11 | 9 | 11 | 4.9 | 1.3 | 0.0 |
| ***Southern Plateau*** | | | | | | | **40.2** | **−1.5** | | | | | | | | | | **68** | **1.91** | **+1.3** | | | | | | | | | | **4.2** | | |
| El Paso | 3,778 | 152 | 175 | 26.21 | 30.05 | +.02 | 45.2 | +0.3 | 73 | 2 | 55 | 21 | 25 | 35 | 32 | 37 | 30 | 61 | 0.75 | +0.2 | 6 | 6,761 | nw. | 50 | w. | 13 | 14 | 9 | 8 | 4.4 | 0.2 | 0.0 |
| Santa Fe | 7,013 | 38 | 53 | 23.19 | 30,10 | +.04 | 29.2 | −1.5 | 60 | 2 | 38 | 3 | 25 | 20 | 31 | 24 | 19 | 74 | 1.46 | +0.7 | 10 | 4,204 | n. | 24 | sw. | 12 | 16 | 7 | 8 | 4.5 | 13.1 | 1.0 |
| Flagstaff | 6,807 | 10 | 59 | 23.28 | 30.04 | −.02 | 24.8 | −3.6 | 63 | 1 | 37 | −14 | 25 | 12 | 46 | 24 | ---- | 79 | 2.83 | ---- | 13 | 5,302 | e. | 35 | n. | 28 | 11 | 7 | 13 | ---- | 18.0 | 4.0 |
| Phoenix | 1,108 | 10 | 82 | 28.84 | 30.02 | −.02 | 51.2 | −0.8 | 77 | 2 | 62 | 26 | 25 | 40 | 40 | 44 | 37 | 64 | 2.68 | +2.1 | 11 | 2,895 | e. | 24 | e. | 12 | 15 | 6 | 10 | 4.6 | 0.0 | 0.0 |
| Yuma | 141 | 9 | 54 | 29.88 | 30.03 | −.02 | 52.4 | −2.8 | 76 | 1 | 62 | 31 | 28 | 42 | 30 | 45 | 37 | 61 | 4.43 | +4.0 | 6 | 3,988 | n. | 29 | n. | 24 | 18 | 9 | 4 | 3.5 | 0.0 | 0.0 |
| Independence | 3,957 | 5 | 25 | 25.96 | 30.08 | −.04 | 38.6 | −0.7 | 64 | 2 | 50 | 13 | 25 | 27 | 36 | 30 | ---- | ---- | 0.22 | −0.6 | 1 | ---- | nw. | ---- | ---- | ---- | 15 | 11 | 5 | ---- | 0.0 | 0.0 |
| ***Middle Plateau*** | | | | | | | **29.3** | **−0.9** | | | | | | | | | | **71** | **1.03** | **+0.1** | | | | | | | | | | **5.3** | | |
| Reno | 4,532 | 74 | 81 | 25.50 | 30.14 | −.01 | 33.8 | +0.1 | 65 | 1 | 43 | 9 | 24 | 24 | 37 | 29 | 24 | 68 | 0.35 | −0.8 | 9 | 4,227 | w. | 44 | sw. | 20 | 12 | 10 | 9 | 4.9 | 2.8 | T. |
| Tonopah | 6,093 | 12 | 20 | 24.03 | 30.12 | ---- | 28.6 | ---- | 54 | 1 | 35 | 5 | 24 | 23 | 19 | 24 | 16 | 58 | 0.26 | ---- | 6 | ---- | nw. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Winnemucca | 4,344 | 18 | 56 | 25.68 | 30.20 | +.02 | 27.2 | −2.8 | 53 | 11 | 39 | −14 | 24 | 16 | 37 | 25 | 21 | 77 | 0.76 | −0.2 | 8 | 5,070 | ne. | 36 | nw. | 11 | 7 | 14 | 10 | 5.9 | 6.9 | 0.2 |
| Modena | 5,473 | 10 | 43 | 24.61 | 30.10 | −.02 | 26.5 | −1.6 | 63 | 1 | 38 | −5 | 23 | 15 | 39 | 22 | 18 | 76 | 0.77 | +0.2 | 7 | 6,058 | w. | 42 | s. | 21 | 19 | 1 | 11 | 4.1 | 1.6 | 0.0 |
| Salt Lake City | 4,360 | 163 | 203 | 25.67 | 30.15 | .00 | 30.6 | −1.3 | 60 | 3 | 37 | 8 | 15 | 24 | 24 | 27 | 22 | 72 | 1.47 | +0.1 | 11 | 3,989 | nw. | 39 | s. | 12 | 8 | 7 | 16 | 6.7 | 12.1 | 2.3 |
| Grand Junction | 4,602 | 60 | 68 | 25.43 | 30.11 | +.01 | 28.4 | +0.9 | 57 | 1 | 37 | 5 | 26 | 20 | 31 | 25 | 20 | 74 | 1.78 | +1.3 | 8 | 2,989 | se. | 29 | sw. | 12 | 10 | 12 | 9 | 5.1 | 2.9 | T. |
| ***Northern Plateau*** | | | | | | | **30.6** | **−0.9** | | | | | | | | | | **82** | **1.57** | **−0.1** | | | | | | | | | | **7.9** | | |
| Baker | 3,471 | 48 | 53 | 26.50 | 30.20 | +.04 | 25.0 | −2.3 | 51 | 1 | 32 | −11 | 14 | 18 | 26 | 24 | 22 | 86 | 1.79 | +0.3 | 16 | 4,265 | se. | 20 | se. | 2 | 5 | 4 | 22 | 7.7 | 17.3 | 4.3 |
| Boise | 2,739 | 78 | 86 | 27.27 | 30.21 | +.01 | 30.2 | −1.9 | 62 | 1 | 38 | −3 | 14 | 23 | 27 | 28 | 24 | 78 | 1.38 | −0.3 | 12 | 3,394 | se. | 30 | nw. | 11 | 7 | 7 | 17 | 6.8 | 13.9 | 2.7 |
| Lewiston | 757 | 40 | 48 | 29.30 | 30.13 | .00 | 36.0 | +0.3 | 56 | 11 | 41 | 5 | 14 | 31 | 20 | ---- | ---- | ---- | 1.24 | −0.3 | 14 | 3,353 | e. | 32 | nw. | 11 | 1 | 5 | 25 | 8.4 | 2.3 | 0.0 |
| Pocatello | 4,477 | 60 | 68 | 25.51 | 30.18 | +.05 | 26.4 | −1.3 | 60 | 1 | 33 | −4 | 15 | 20 | 27 | 23 | 20 | 80 | 1.32 | +0.5 | 13 | 6,097 | se. | 36 | se. | 21 | 3 | 10 | 18 | 7.6 | 11.7 | 4.5 |
| Spokane | 1,929 | 101 | 110 | 28.02 | 30.13 | +.05 | 30.4 | −0.1 | 55 | 1 | 35 | 1 | 14 | 26 | 16 | 30 | 27 | 87 | 1.72 | −0.5 | 15 | 4,086 | s. | 30 | sw. | 11 | 2 | 4 | 25 | 8.9 | 12.8 | 3.7 |
| Walla Walla | 991 | 57 | 65 | 29.03 | 30.13 | +.01 | 35.4 | −0.1 | 68 | 1 | 42 | 4 | 14 | 28 | 29 | 33 | 29 | 77 | 1.98 | −0.1 | 17 | 3,932 | s. | 29 | se. | 20 | 6 | 2 | 23 | 7.8 | 9.0 | 0.0 |
| ***North Pacific Coast Region*** | | | | | | | **42.4** | **+0.2** | | | | | | | | | | **88** | **6.35** | **−1.1** | | | | | | | | | | **8.2** | | |
| North Head | 211 | 11 | 56 | 29.83 | 30.06 | +.03 | 44.0 | −0.1 | 59 | 1 | 48 | 24 | 14 | 40 | 16 | 43 | 41 | 90 | 8.39 | +0.9 | 25 | 13,102 | se. | 95 | s. | 1 | 2 | 3 | 26 | 8.8 | 0.2 | 0.0 |
| Port Angeles | 29 | 8 | 53 | ---- | 30.05 | ---- | 40.6 | ---- | 62 | 31 | 46 | 18 | 13 | 35 | 20 | ---- | ---- | ---- | 4.28 | −0.9 | 20 | 4,515 | sw. | 34 | w. | 11 | 0 | 4 | 27 | ---- | 0.5 | 0.0 |
| Seattle | 125 | 215 | 250 | 29.93 | 30.06 | +.05 | 41.6 | −0.1 | 60 | 1 | 46 | 20 | 14 | 38 | 17 | 40 | 38 | 80 | 4.03 | −1.4 | 23 | 6,787 | s. | 65 | s. | 1 | 1 | 6 | 24 | 8.7 | 5.5 | 0.0 |
| Tacoma | 194 | 172 | 201 | 29.86 | 30.06 | +.05 | 41.4 | +0.8 | 62 | 1 | 46 | 16 | 14 | 36 | 19 | ---- | ---- | ---- | 4.06 | −2.8 | 20 | 5,230 | s. | 54 | sw. | 1 | 0 | 4 | 27 | 8.6 | 5.6 | 0.0 |
| Tatoosh Island | 86 | 9 | 53 | 29.91 | 30.01 | +.09 | 44.1 | +0.2 | 56 | 30 | 47 | 20 | 13 | 42 | 16 | 42 | 41 | 90 | 13.58 | −1.0 | 25 | 14,475 | e. | 66 | s. | 28 | 3 | 7 | 21 | 8.0 | 2.0 | 0.0 |
| Yakima | 1,071 | 5 | ---- | ---- | ---- | ---- | 27.8 | ---- | 54 | 2 | 37 | −6 | 23 | 19 | 34 | ---- | ---- | ---- | 1.19 | ---- | 5 | ---- | nw. | ---- | ---- | ---- | 3 | 16 | 12 | 6.3 | 10.3 | 2.0 |
| Medford | 1,425 | 4 | ---- | ---- | ---- | ---- | 37.9 | ---- | 67 | 1 | 44 | 18 | 14 | 32 | 28 | ---- | ---- | ---- | 3.06 | ---- | 14 | ---- | se. | ---- | ---- | ---- | 1 | 8 | 22 | ---- | T. | 0.0 |
| Portland, Oreg. | 153 | 68 | 106 | 29.95 | 30.12 | +.05 | 41.0 | −0.2 | 63 | 1 | 46 | 19 | 14 | 36 | 17 | 39 | 37 | 86 | 5.91 | −1.0 | 18 | 3,981 | se. | 28 | sw. | 24 | 0 | 5 | 26 | 8.9 | 4.2 | 0.0 |
| Roseburg | 510 | 9 | 57 | 29.58 | 30.14 | +.03 | 42.6 | +0.8 | 67 | 1 | 49 | 25 | 14 | 36 | 26 | 41 | 38 | 84 | 4.17 | −1.8 | 20 | 2,262 | s. | 23 | s. | 17 | 2 | 7 | 22 | 8.1 | T. | 0.0 |
| ***Middle Pacific Coast Region*** | | | | | | | **48.5** | **−0.2** | | | | | | | | | | **73** | **2.68** | **−1.8** | | | | | | | | | | **4.2** | | |
| Eureka | 62 | 73 | 89 | 30.08 | 30.14 | +.02 | 47.6 | −0.6 | 66 | 30 | 54 | 29 | 14 | 41 | 26 | 45 | 41 | 79 | 6.47 | −0.8 | 18 | 6,351 | se. | 35 | n. | 11 | 8 | 8 | 15 | 6.2 | 0.0 | 0.0 |
| Point Reyes | 490 | 7 | 18 | 29.52 | 30.04 | ---- | 51.0 | +0.4 | 66 | 10 | 55 | 39 | 13 | 47 | 16 | ---- | ---- | ---- | 3.39 | ---- | 10 | 14,287 | nw. | 82 | nw. | 6 | 18 | 6 | 7 | 3.6 | 0.0 | 0.0 |
| Red Bluff | 332 | 50 | 56 | 29.77 | 30.14 | .00 | 46.6 | +0.5 | 71 | 10 | 54 | 28 | 31 | 39 | 28 | 42 | 36 | 69 | 4.12 | −0.4 | 9 | 4,901 | nw. | 35 | nw. | 7 | 13 | 12 | 6 | 4.6 | 0.0 | 0.0 |
| Sacramento | 69 | 106 | 117 | 30.04 | 30.11 | −.05 | 46.4 | +0.2 | 63 | 10 | 54 | 27 | 26 | 39 | 25 | 43 | 39 | 76 | 0.58 | −3.0 | 7 | 5,827 | se. | 34 | nw. | 7 | 19 | 9 | 3 | 3.0 | 0.0 | 0.0 |
| San Francisco | 155 | 208 | 243 | 29.93 | 30.10 | −.02 | 51.5 | +0.2 | 68 | 4 | 56 | 39 | 26 | 46 | 15 | 46 | 40 | 68 | 1.04 | −3.2 | 7 | 5,482 | n. | 50 | ne. | 8 | 12 | 13 | 6 | 4.3 | 0.0 | 0.0 |
| San Jose | 141 | 12 | 110 | 29.95 | 30.11 | ---- | 47.9 | −2.0 | 69 | 10 | 58 | 28 | 26 | 38 | 29 | ---- | ---- | ---- | 1.17 | −1.4 | 10 | 4,437 | nw. | 33 | n. | 8 | 18 | 7 | 6 | 3.4 | 0.0 | 0.0 |
| ***South Pacific Coast Region*** | | | | | | | **52.3** | **−0.6** | | | | | | | | | | **68** | **1.76** | **−0.4** | | | | | | | | | | **4.0** | | |
| Fresno | 327 | 89 | 98 | 29.74 | 30.11 | −.02 | 46.6 | +0.4 | 76 | 1 | 55 | 29 | 24 | 38 | 31 | 43 | 39 | 78 | 0.58 | −1.0 | 5 | 3,155 | nw. | 22 | nw. | 12 | 14 | 8 | 9 | 4.3 | 0.0 | 0.0 |
| Los Angeles | 338 | 159 | 191 | 29.66 | 30.02 | −.05 | 56.1 | −0.5 | 76 | 1 | 64 | 40 | 26 | 48 | 26 | 47 | 38 | 56 | 1.15 | −1.8 | 7 | 4,070 | ne. | 36 | ne. | 8 | 17 | 4 | 10 | 3.8 | 0.0 | 0.0 |
| San Diego | 87 | 62 | 70 | 29.92 | 30.02 | −.05 | 55.2 | −0.8 | 70 | 30 | 62 | 37 | 27 | 48 | 27 | 50 | 45 | 73 | 3.89 | +2.1 | 14 | 4,318 | e. | 31 | s. | 9 | 11 | 8 | 12 | 5.2 | 0.0 | 0.0 |
| San Luis Obispo | 201 | 32 | 40 | 29.86 | 30.09 | −.02 | 51.4 | −1.6 | 73 | 10 | 62 | 30 | 25 | 40 | 40 | 44 | 37 | 64 | 1.41 | −0.9 | 8 | 2,842 | n. | 24 | ne. | 8 | 21 | 7 | 3 | 2.7 | 0.0 | 0.0 |
| ***West Indies*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| San Juan, P. R. | 82 | 9 | 54 | 29.88 | 29.97 | ---- | 76.0 | −0.3 | 83 | 2 | 80 | 67 | 31 | 72 | 13 | ---- | ---- | ---- | 2.21 | −3.9 | 20 | 11,009 | e. | 44 | e. | 5 | 3 | 20 | 8 | 5.8 | 0.0 | 0.0 |
| ***Panama Canal*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Balboa Heights | 118 | 7 | 97 | [1] 29.72 | [1] 29.84 | .00 | 79.4 | −0.5 | 90 | 28 | 86 | 70 | 30 | 72 | 18 | 74 | 74 | 87 | 8.38 | +4.1 | 22 | 3,936 | nw. | 25 | n. | 18 | 2 | 15 | 14 | 6.9 | 0.0 | 0.0 |
| Colon | 38 | 7 | 97 | [1] 29.82 | [1] 29.86 | .00 | 80.6 | +0.6 | 89 | 28 | 86 | 73 | 31 | 75 | 15 | 76 | 75 | 82 | 7.60 | −3.3 | 27 | 6,539 | n. | 25 | n. | 20 | 2 | 15 | 14 | 6.7 | 0.0 | 0.0 |
| ***Alaska*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Juneau | 80 | 11 | 54 | [1] 29.57 | 29.66 | ---- | 32.4 | ---- | 47 | 8 | 36 | 13 | 14 | 29 | 16 | 31 | 28 | 83 | 14.43 | ---- | 29 | 7,350 | s. | 35 | e. | 11 | 2 | 2 | 27 | 9.1 | 31.3 | 0.0 |
| ***Hawaiian Islands*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Honolulu | 38 | 86 | 100 | [1] 29.97 | 30.01 | ---- | 75.0 | ---- | 84 | 11 | 80 | 66 | 30 | 70 | 13 | 69 | 65 | 76 | 1.93 | −2.0 | 17 | 5,519 | e. | 34 | e. | 25 | 8 | 16 | 7 | 5.5 | 0.0 | 0.0 |

[1] Pressure not corrected to mean 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, December, 1926*

| Stations | Altitude above mean sea level Jan. 1, 1919 | Pressure | | | Temperature of the air | | | | | | Precipitation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Station reduced to mean of 24 hours | Sea level reduced to mean of 24 hours | Departure from normal | Mean max. + mean min. ÷ 2 | Departure from normal | Mean maximum | Mean minimum | Highest | Lowest | Total | Departure from normal | Total snowfall |
| | *Feet* | *Inches* | *Inches* | *Inches* | °*F.* | °*F.* | °*F.* | °*F.* | °*F.* | °*F.* | *Inches* | *Inches* | *Inches* |
| St. Johns, N. F. | 125 | | | | | | | | | | | | |
| Sydney, C. B. I. | 48 | | | | | | | | | | | | |
| Halifax, N. S. | 88 | | | | | | | | | | | | |
| Yarmouth, N. S. | 65 | | | | | | | | | | | | |
| Charlottetown, P. E. I. | 38 | | | | | | | | | | | | |
| Chatham, N. B. | 28 | | | | | | | | | | | | |
| Father Point, Que. | 20 | | | | | | | | | | | | |
| Quebec, Que. | 296 | 29.71 | 30.05 | +.04 | 14.5 | −0.7 | 20.3 | 8.7 | 36 | −10 | 2.37 | −1.32 | 22.8 |
| Montreal, Que. | 187 | 29.85 | 30.07 | +.04 | 16.6 | −1.7 | 22.6 | 10.7 | 39 | −5 | 3.63 | −0.02 | 35.4 |
| Stonecliffe, Ont. | 489 | | | | | | | | | | | | |
| Ottawa, Ont. | 236 | 29.82 | 30.11 | +.09 | 15.5 | −1.5 | 22.7 | 8.3 | 36 | −10 | 1.95 | −0.96 | 17.3 |
| Kingston, Ont. | 285 | 29.77 | 30.11 | +.07 | 20.6 | −3.1 | 27.1 | 14.2 | 40 | −9 | 1.92 | −1.32 | 15.0 |
| Toronto, Ont. | 379 | 29.65 | 30.08 | +.03 | 23.9 | −3.1 | 30.1 | 17.8 | 43 | −3 | 1.45 | −1.46 | 10.9 |
| Cochrane, Ont. | 930 | | | | 8.0 | | 17.1 | −1.0 | 32 | −28 | | | |
| White River, Ont. | 1,244 | 28.60 | 29.98 | +.01 | 7.9 | −1.8 | 18.2 | −2.4 | 32 | −42 | 1.49 | −0.22 | 14.9 |
| Southampton, Ont. | 656 | 29.32 | 30.06 | +.04 | 22.2 | −4.5 | 27.8 | 16.6 | 44 | −3 | 3.56 | −0.42 | 31.1 |
| Parry Sound, Ont. | 688 | 29.33 | 30.06 | +.05 | 17.8 | −3.4 | 24.4 | 11.2 | 38 | −20 | 3.56 | −0.92 | 33.2 |
| Port Arthur, Ont. | 644 | 29.30 | 30.04 | +.05 | 10.7 | −2.5 | 18.6 | 2.8 | 34 | −23 | 1.41 | +0.54 | 14.1 |
| Winnipeg, Man. | 760 | | | | | | | | | | | | |
| Minnedosa, Man. | 1,690 | 28.08 | 30.01 | −.01 | 2.8 | −2.9 | 12.0 | −6.3 | 36 | −32 | 0.95 | +0.33 | 9.5 |
| Le Pas, Man. | 860 | | | | −1.4 | | 8.0 | −10.8 | 34 | −38 | 1.38 | | 13.8 |
| Qu'Appelle, Sask. | 2,115 | 27.60 | 29.97 | −.03 | 4.8 | −2.6 | 13.3 | −3.7 | 38 | −35 | 0.74 | +0.22 | 7.0 |
| Medicine Hat, Alb. | 2,144 | 27.60 | 29.96 | −.01 | 16.4 | −1.8 | 25.3 | 7.5 | 55 | −20 | 2.15 | +1.60 | 21.5 |
| Moose Jaw, Sask. | 1,759 | | | | 7.5 | | 15.9 | −0.9 | 42 | −29 | 0.57 | | 5.6 |
| Swift Current, Sask. | 2,392 | 27.33 | 29.99 | .00 | 11.3 | −4.7 | 20.7 | 1.9 | 42 | −27 | 0.40 | −0.38 | 3.4 |
| Calgary, Alb. | 3,428 | | | | | | | | | | | | |
| Banff, Alb. | 4,521 | 25.28 | 30.07 | +.13 | 14.3 | −4.8 | 22.0 | 6.6 | 44 | −37 | 1.19 | −0.02 | 11.7 |
| Edmonton, Alb. | 2,150 | 27.53 | 29.92 | −.01 | 11.4 | −1.7 | 20.7 | 2.1 | 46 | −35 | 1.47 | +0.77 | 10.9 |
| Prince Albert, Sask. | 1,450 | 28.35 | 30.02 | −.01 | 3.7 | +0.9 | 12.4 | −4.9 | 43 | −28 | 0.49 | −0.25 | 4.9 |
| Battleford, Sask. | 1,592 | 28.20 | 30.05 | +.06 | 1.4 | −4.0 | 9.2 | −6.5 | 40 | −30 | 0.47 | +0.15 | 2.2 |
| Kamloops, B. C. | 1,262 | | | | | | | | | | | | |
| Victoria, B. C. | 230 | 29.79 | 30.05 | +.08 | 41.4 | +0.2 | 45.2 | 37.7 | 55 | 19 | 3.88 | −4.10 | 1.0 |
| Barkerville, B. C. | 4,180 | | | | | | | | | | | | |
| Triangle Island, B. C. | 680 | | | | | | | | | | | | |
| Prince Rupert, B. C. | 170 | | | | | | | | | | | | |
| Hamilton, Ber. | 151 | 29.96 | 30.13 | +.01 | 64.3 | −0.4 | 71.0 | 57.6 | 76 | 51 | 4.38 | −0.11 | |
| **LATE REPORTS, NOVEMBER, 1926** | | | | | | | | | | | | | |
| Sydney, C. B. I. | 48 | 30.06 | 30.11 | +.16 | 39.2 | +2.1 | 46.2 | 32.3 | 61 | 20 | 3.67 | −1.77 | 0.5 |
| Halifax, N. S. | 88 | | | | 40.4 | +3.1 | 47.8 | 32.9 | 62 | 20 | 4.51 | −1.15 | |
| Yarmouth, N. S. | 65 | 29.97 | 30.04 | +.02 | 41.5 | +1.6 | 48.8 | 34.3 | 63 | 18 | 2.92 | −1.64 | 0.2 |
| Charlottetown, P. E. I. | 38 | 30.01 | 30.05 | +.09 | 38.3 | +2.8 | 44.7 | 31.9 | 59 | 21 | 2.05 | −1.92 | 0.5 |
| Chatham, N. B. | 28 | 29.94 | 29.97 | .00 | 33.1 | +2.1 | 40.9 | 25.3 | 65 | 9 | 3.24 | −0.51 | 5.5 |
| Kamloops, B. C. | 1,262 | 28.70 | 30.02 | +.06 | 36.7 | +3.3 | 42.2 | 31.2 | 50 | 15 | 0.58 | −0.88 | 1.0 |
| Barkerville, B. C. | 4,180 | 25.57 | 29.93 | +.03 | 28.7 | +5.1 | 34.2 | 23.2 | 52 | 6 | 3.61 | +0.32 | 27.0 |

O

**Chart I. Tracks of Centers of Anticyclones, December, 1926. (Inset) Departure of Monthly Mean Pressure from Normal**
**(Plotted by Wilfred P. Day)**

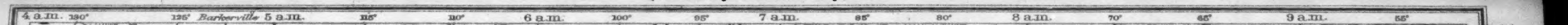
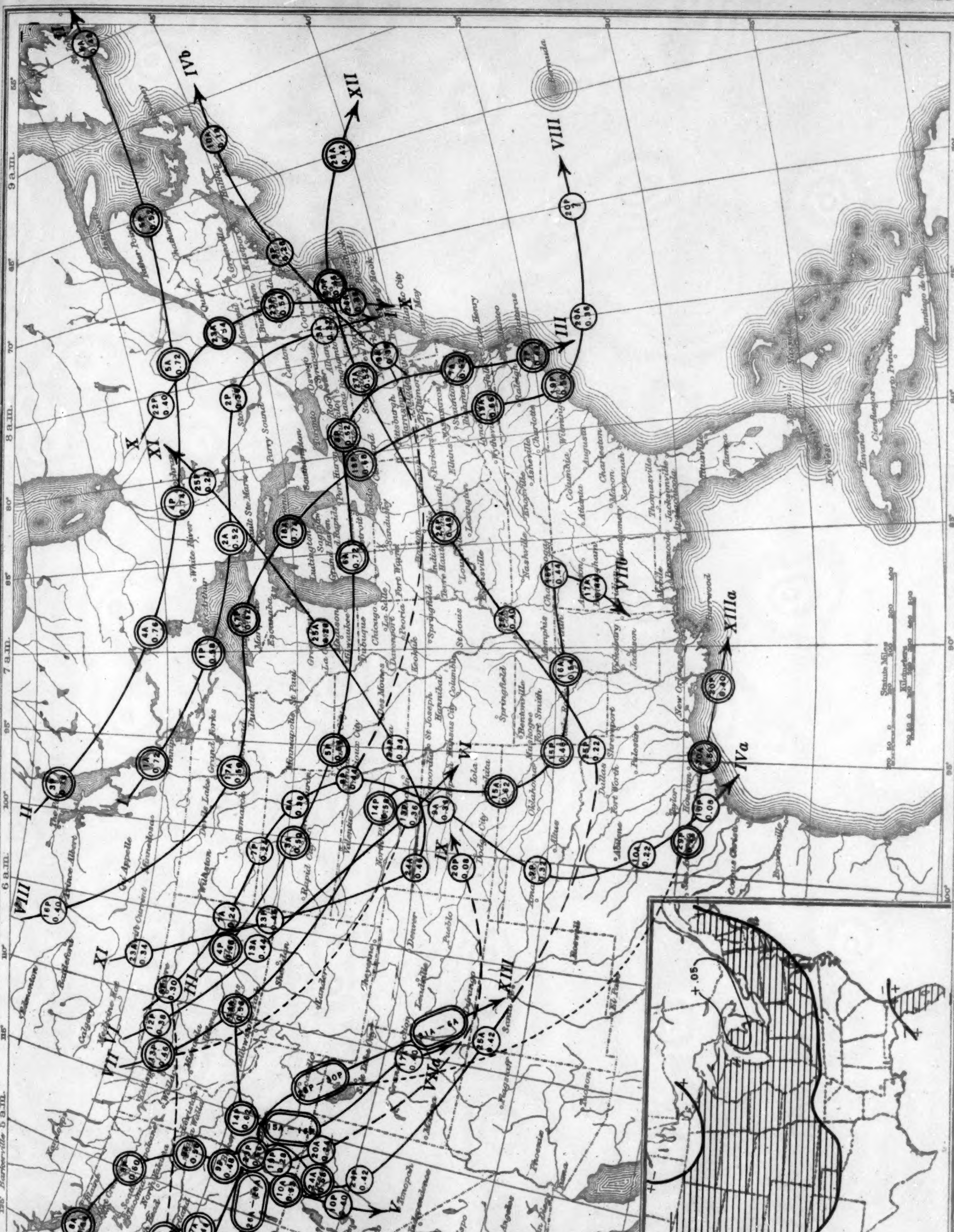


Chart I. Tracks of Centers of Anticyclones, December, 1926. (Inset) Departure of Monthly Mean Pressure from Normal
(Plotted by Wilfred P. Day)



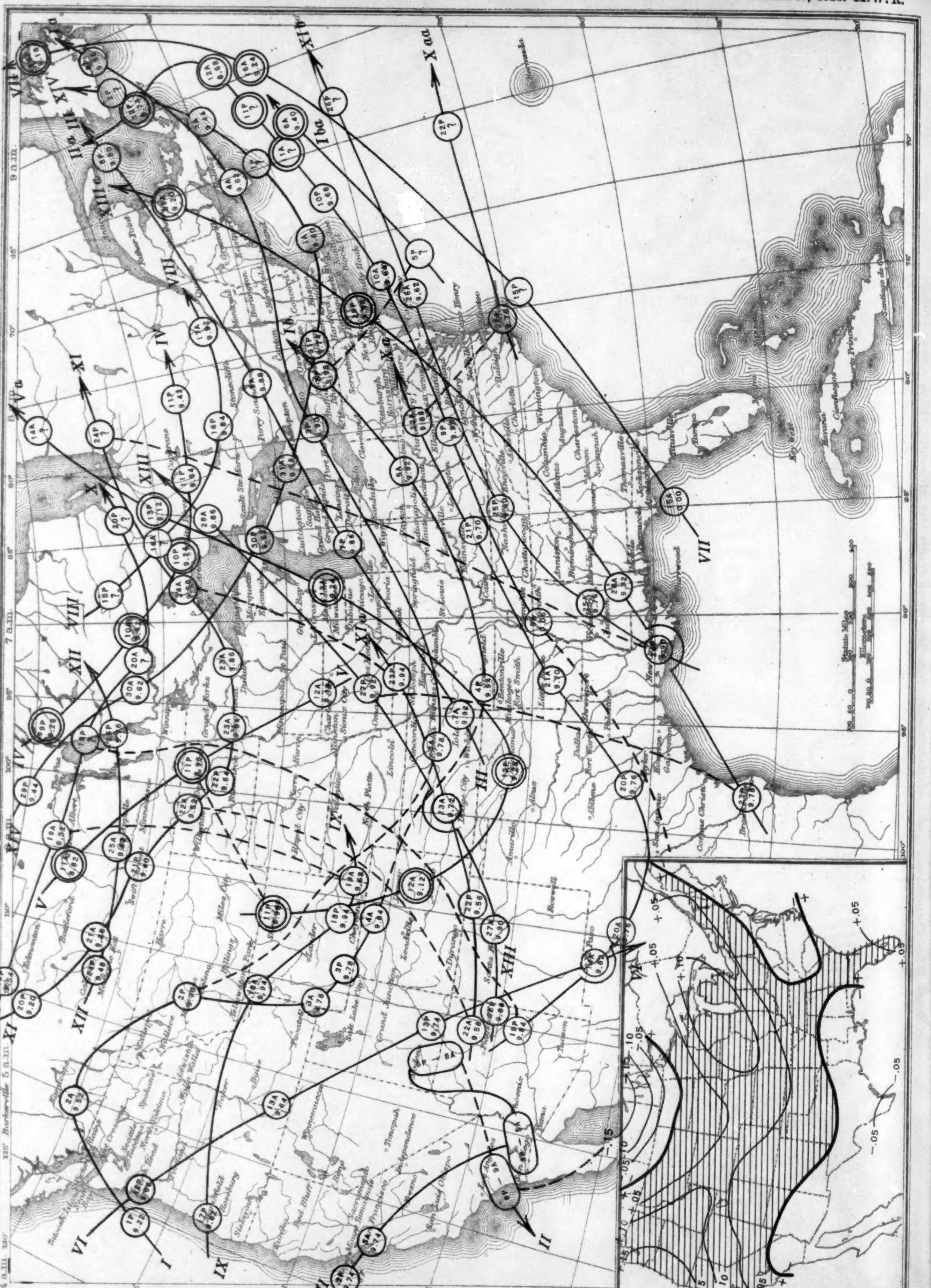


Chart II. Tracks of Centers of Cyclones, December, 1926. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)

Chart III. Departure (°F.) of the Mean Temperature from the Normal, December, 1926

Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart IV. Total Precipitation, Inches, December, 1926. (Inset) Departure of Precipitation from Normal

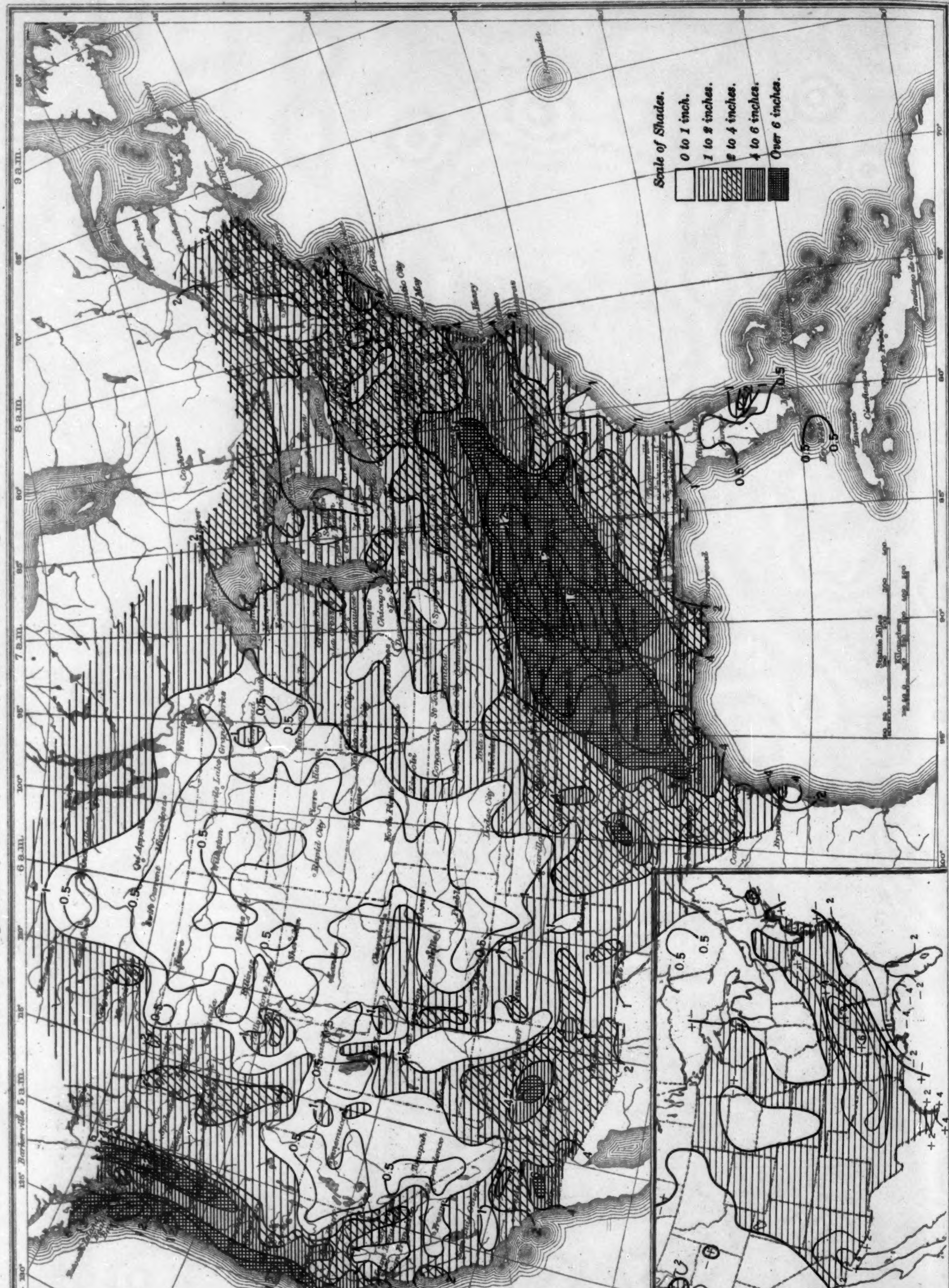



Chart V. Percentage of Clear Sky between Sunrise and Sunset, December, 1926

**Chart V. Percentage of Clear Sky between Sunrise and Sunset, December, 1926**

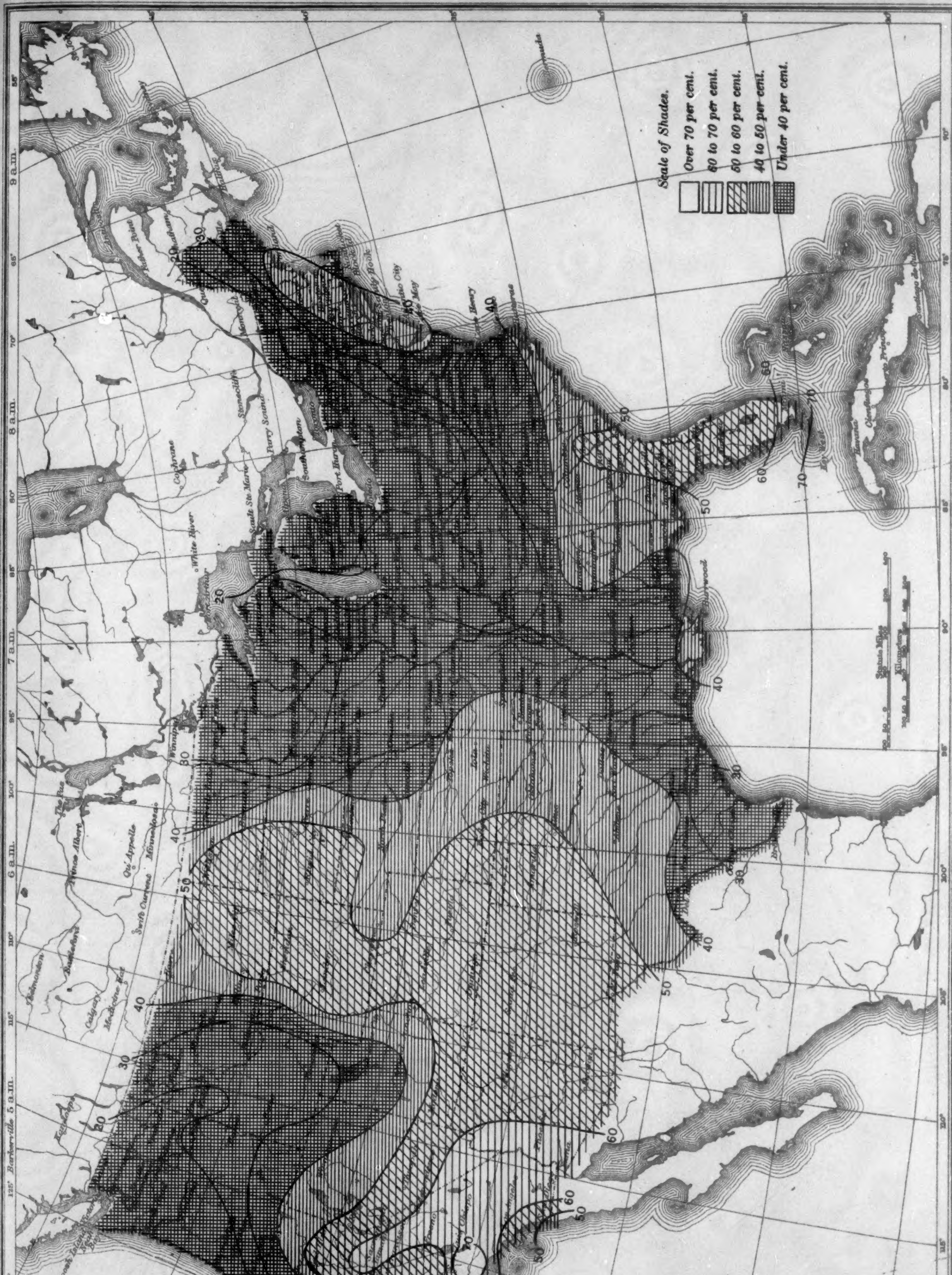


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, December, 1926

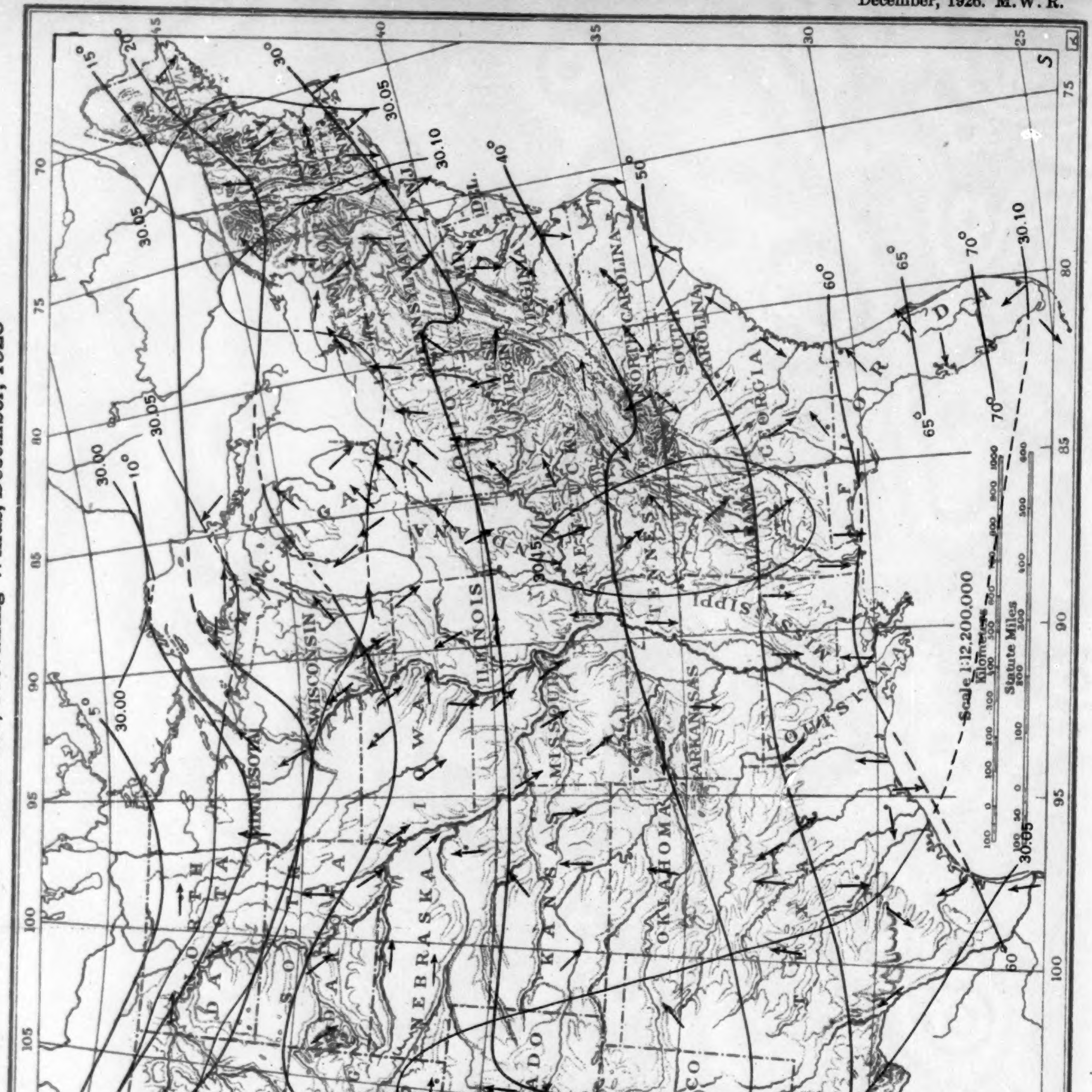


Chart VII. Total Snowfall, Inches, December, 1926. (Inset) Depth of Snow on Ground at end of Month

**Chart VIII. Weather Map of North Atlantic Ocean, December 22, 1926**
(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, December 22, 1926
(Plotted by F. A. Young)

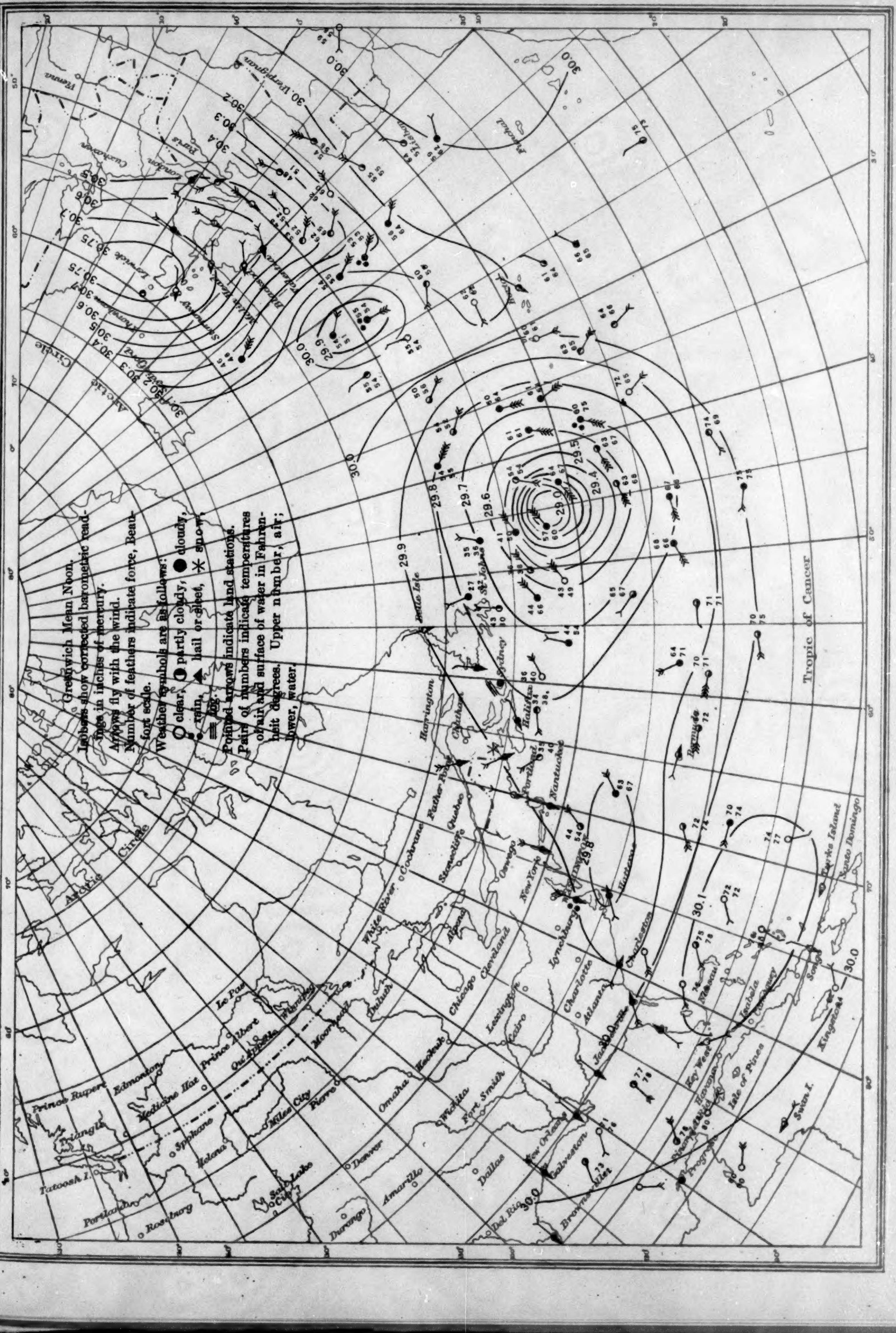


Chart IX. Weather Map of North Atlantic Ocean, December 23, 1926
(Plotted by F. A. Young)

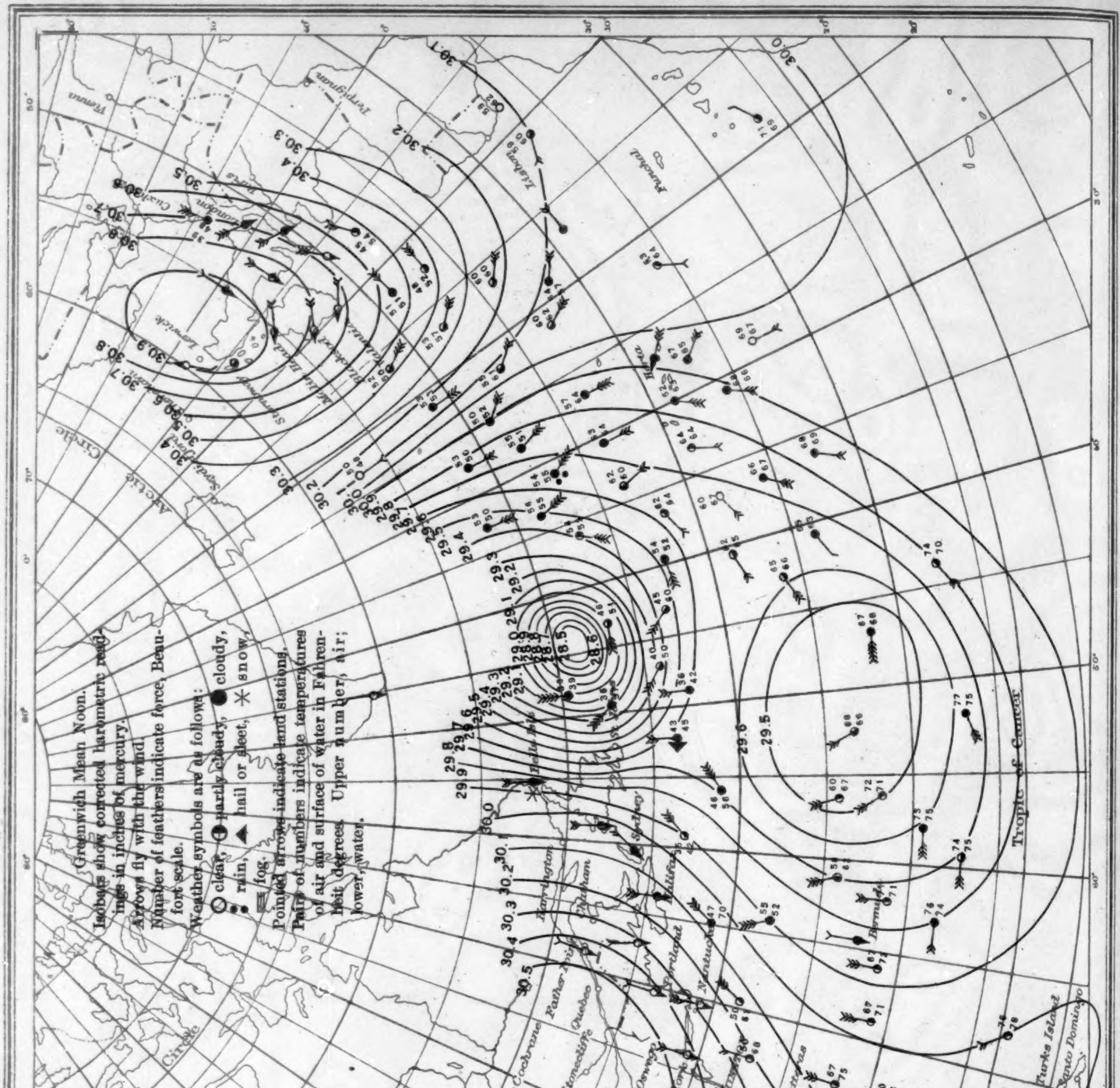
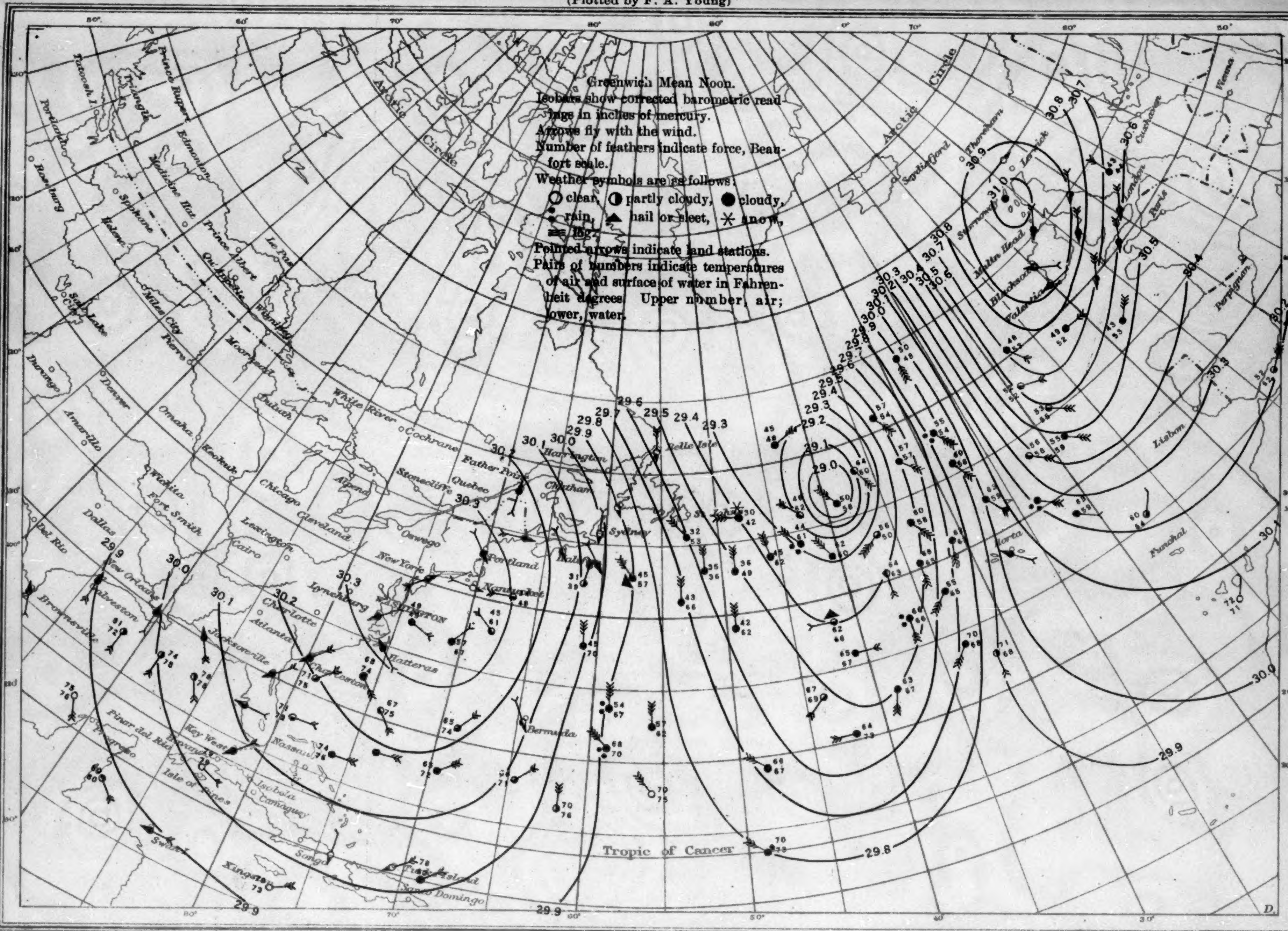



Chart X. Weather Map of North Atlantic Ocean, December 24, 1926
(Plotted by F. A. Young)

## Chart X. Weather Map of North Atlantic Ocean, December 24, 1926

(Plotted by F. A. Young)



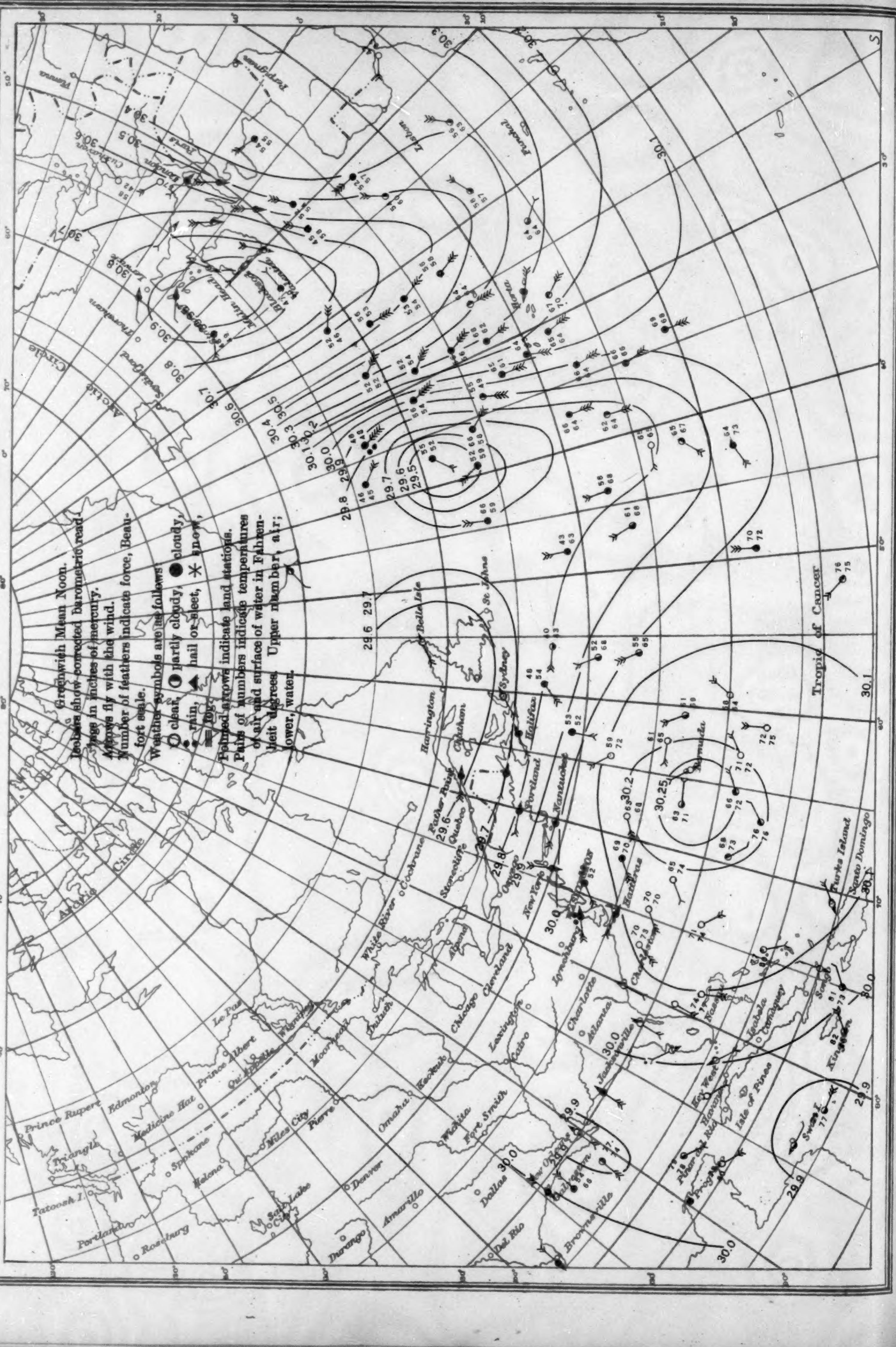



Chart XI. Weather Map of North Atlantic Ocean, December 25, 1926
(Plotted by F. A. Young)

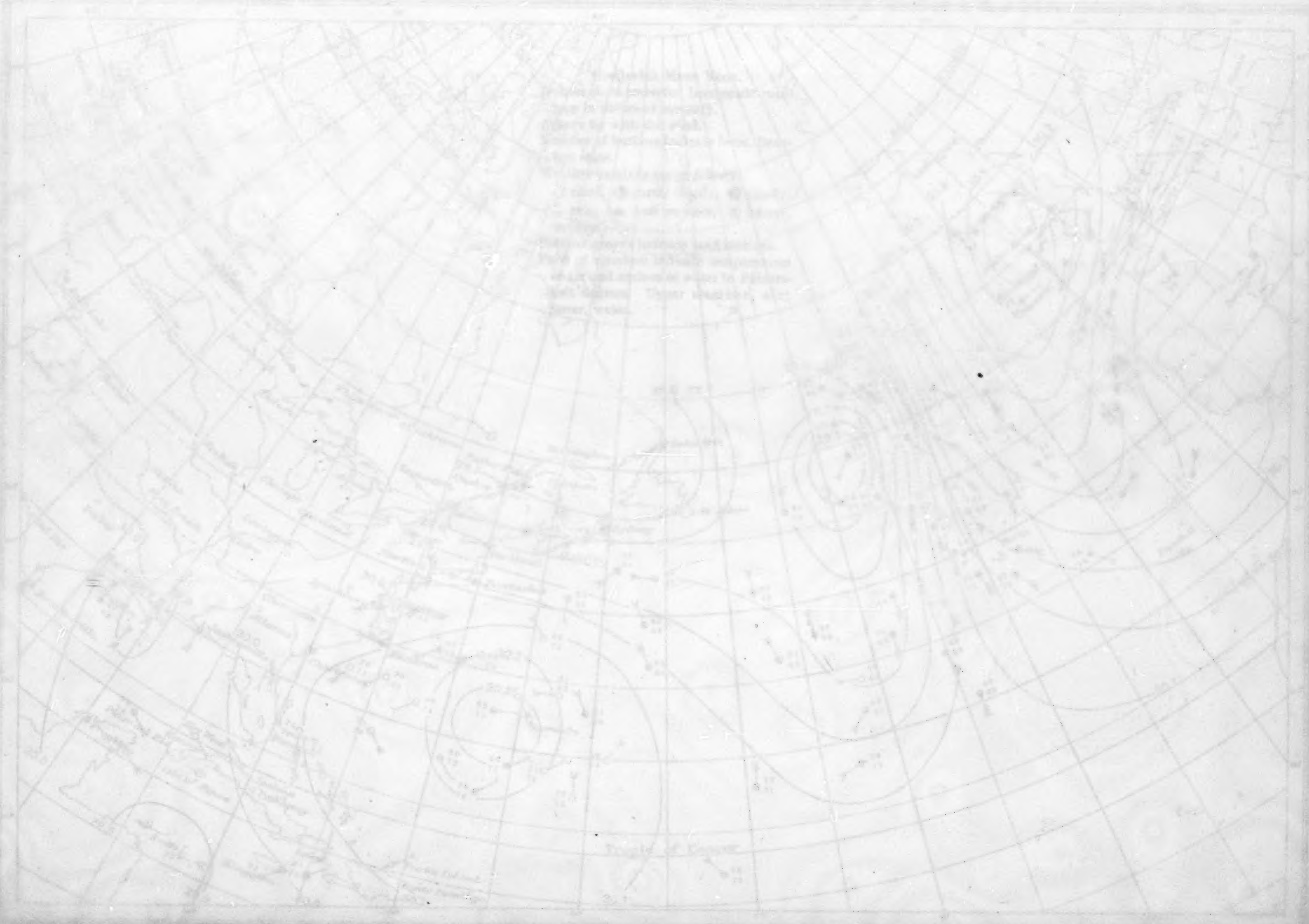



Chart XI. Weather Map of North Atlantic Ocean, December 26, 1908
(Plotted by F. A. Young)

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